GABLS4-LES: une intercomparaison des modèles LES dans des conditions extrêmement stables observées en Antarctique

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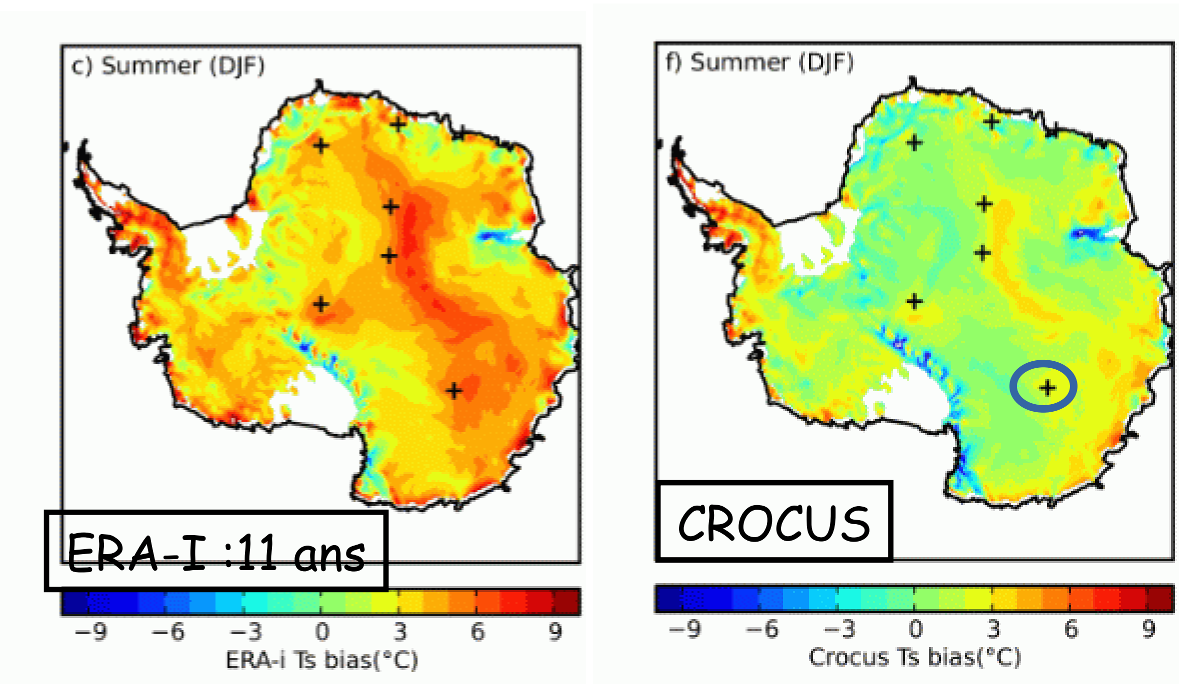
Défaut des paramétrisations en conditions stables => un nouveau cas GABLS

- En conditions de forte stabilité de l'atmosphère et selon la paramétrisation utilisée, les modèles NWP & GCM présentent un excès de mélange des basses couches ou un fort découplage à la surface → biais chaud ou froid (Holtslag et al 2013) => besoin de référence (LES) pour le développement de paramétrisations
- Une 4eme intercomparaison GABLS => focus sur des conditions très stables (Ri > 1), avec interaction avec la surface (surface simple=neige), observations dataset



Biais de température de surface /MODIS (Freville et al. 2014)

Questions :

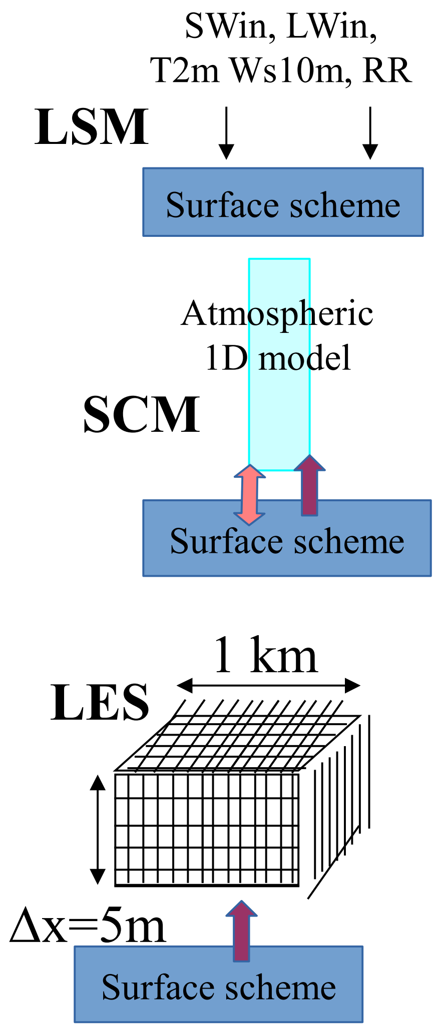
- peut on reproduire les observations de la tour avec les LES ?

- pour une résolution et un forçage donnés, comment différentes LES se comparent elles ?

- quelle est la résolution nécessaire pour résoudre les principaux processus dans un tel cas ?

GABLS4: 3 intercomparaisons en 1

- **Stage 0:** Land Surface Model (LSM=snow scheme) driven by observations for 15 days
- **Stage 1:** Single Column Model (SCM) with all the physics and surface interaction: 36h forecast starting the 11th Dec 2009.
- **Stage 2:** Large-Eddy Simulation (LES) and SCM, stage1 atmospheric forcing but **prescribed** surface temperature

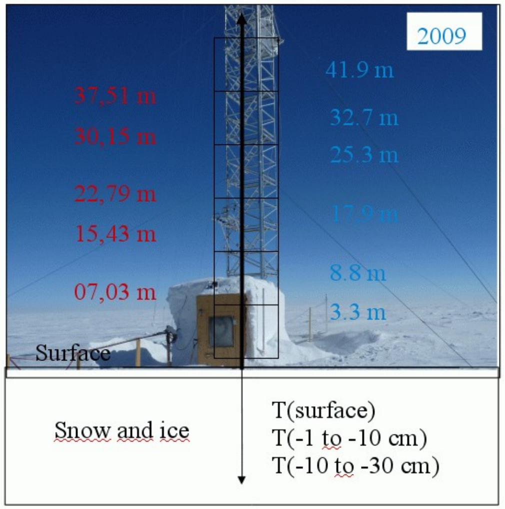


- **Stage 3**: LES and SCM. "ideal GABLS4" or simplified: no radiation, no specific humidity, constant geostrophic wind, no advection, Ts prescribed. Easier for the LES community and DNS

Observations dataset: Concordia

-5 sonic anemometers (7,15, 23,30,38m)

- low fqcy parameters (3,9,18,25,33,42m)
- radiation measurements

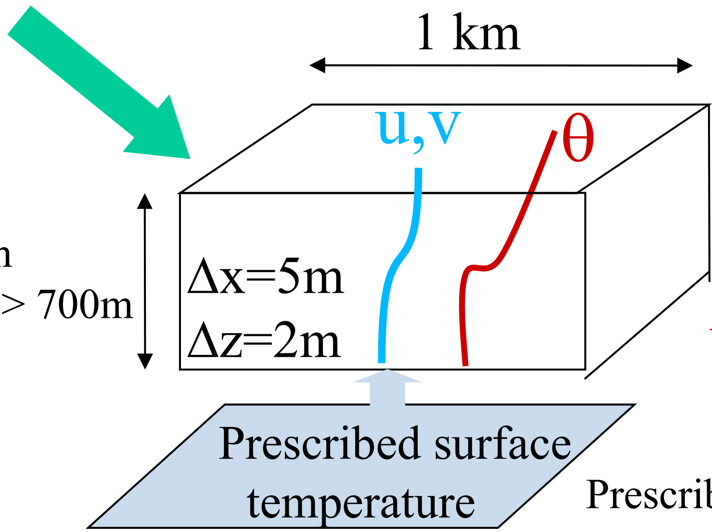


Stage 3 : setup & LES participantes

LS forcing :
No T & q advection
Constant geostrophic wind

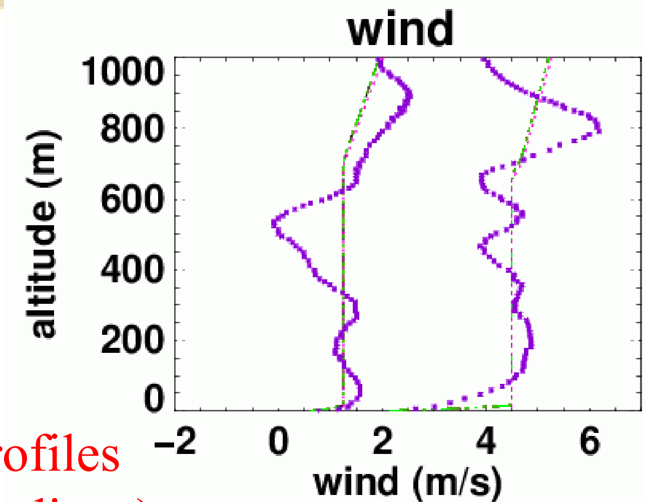
Parametrizations:
- turbulence scheme
-surface scheme or MO similarity
- no radiative scheme

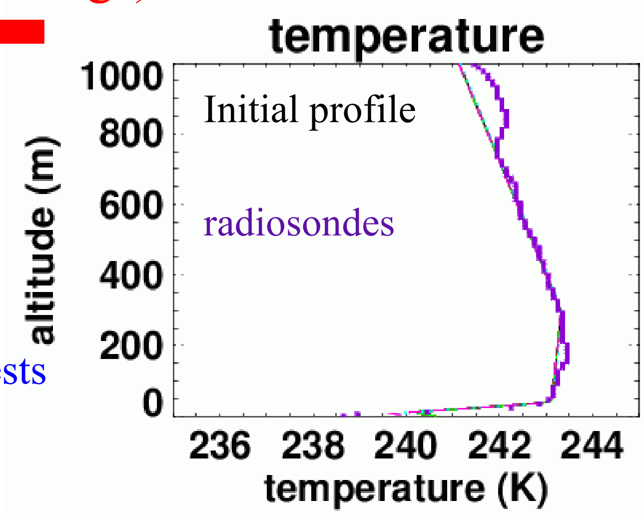
Top =500m-1 km
Absorbing layer > 700m



Prescribed zo

Initial profiles
(from soundings)





No moisture

LES :
MNH *(Lafore et al 98)*: sensitivity tests to zo
PALM *(Maronga et al 15)*: sensitivity tests Δx=2m, 1m ; Lx=2km
MicroHH *(Van Stratum et al, 15)*: over a wider domain Lx=3km + sensitivity tests to Δx, Δz (2,1,0.5,0.25m)
JPL-LES *(Matheou and Chung 2014)* : tests to zo, Δx=2m and subgrid scheme
SAM-LES *(Khairoutdinov and Randall 2003 ; Cheng et al, 2011)* : -
CLMM-LES *(Fuka et al, 2011)*: - sensitivity tests to subgrid scheme
NCSU-LES *(Basu et al, 2008)* : only Δx=Δz=10m
UKMO-LES *(Edwards et al, xxx)*: -

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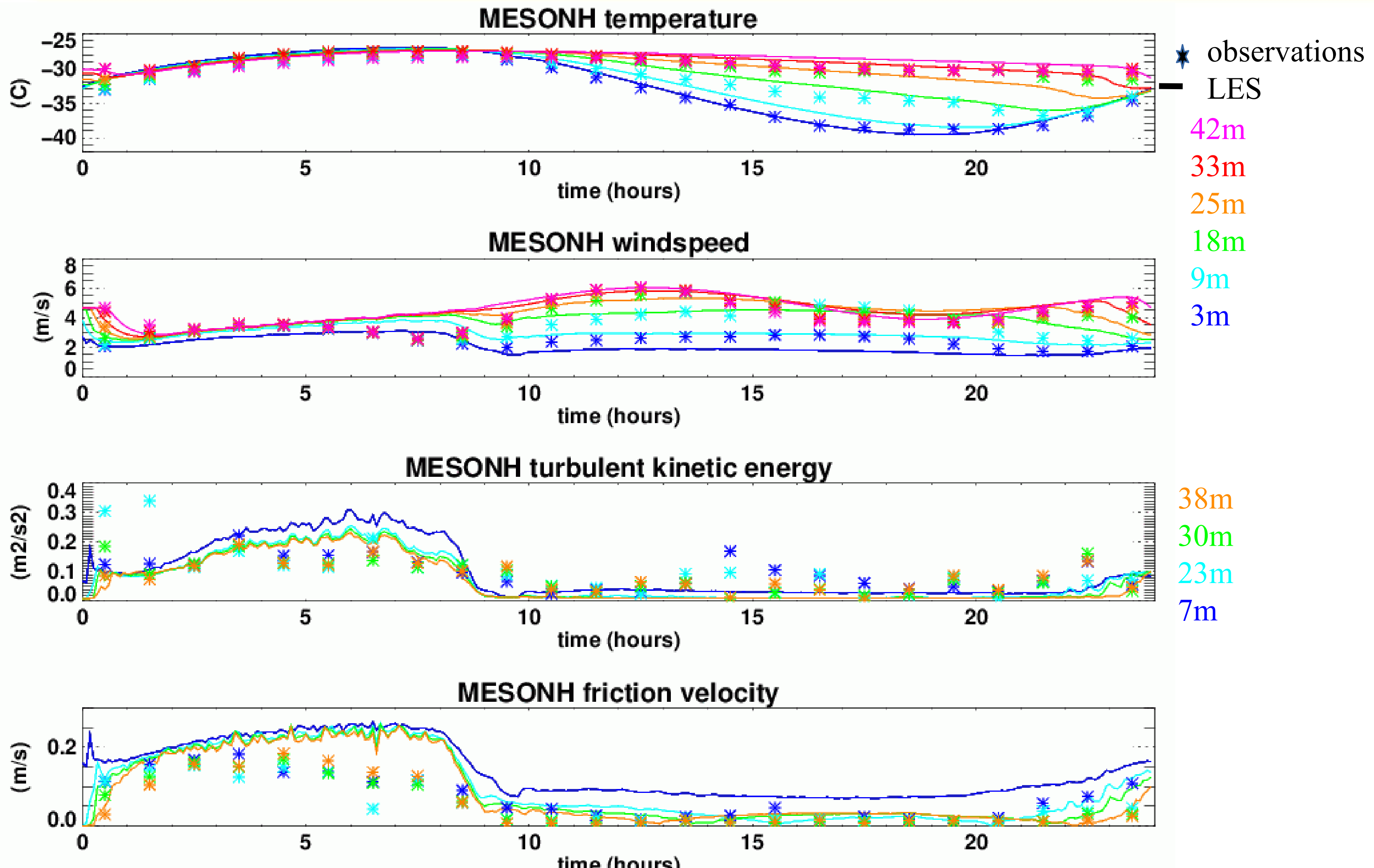
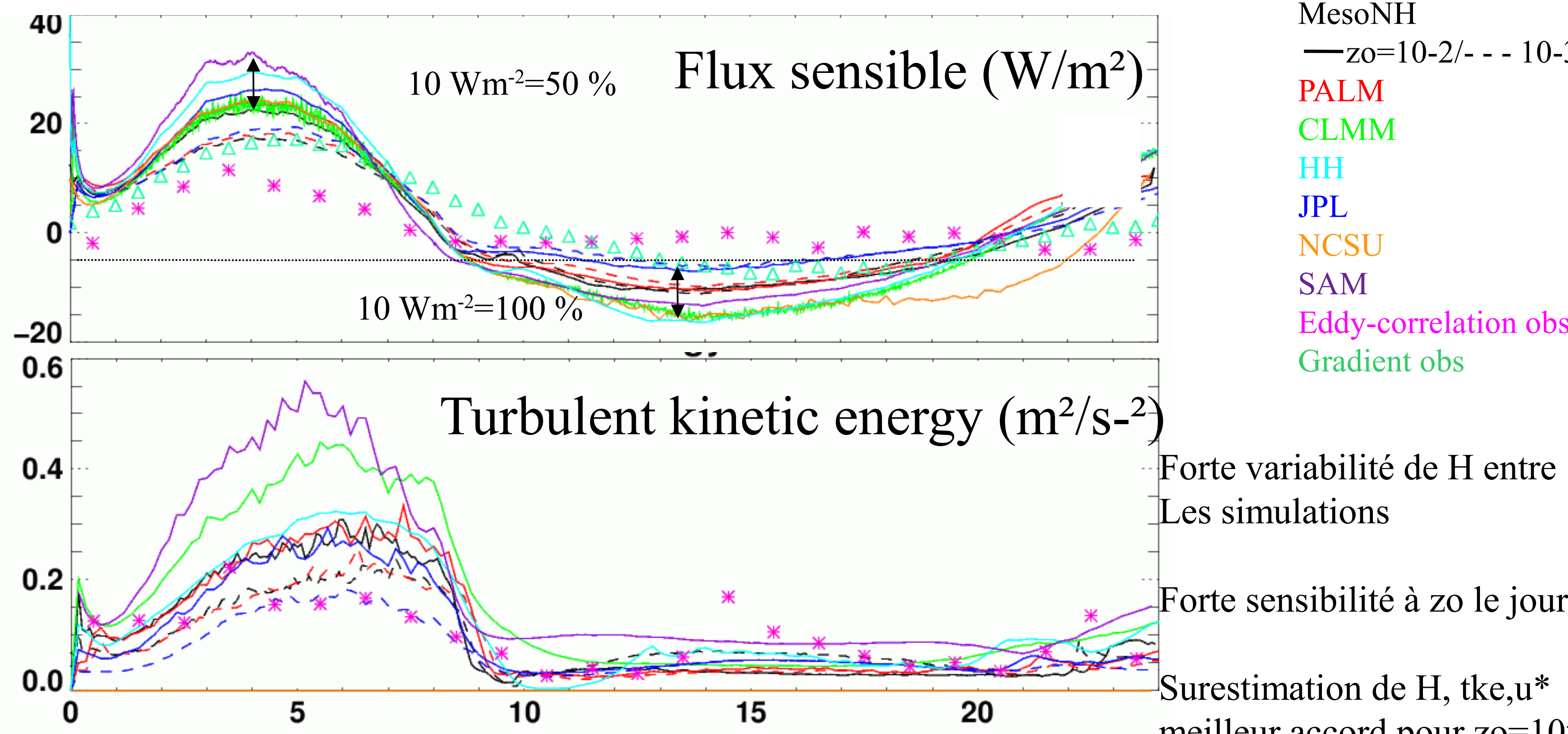
LES Meso-NH : comparaison aux observations de la tour



- gradient régulier dans les 40m dans LES alors que + fort dans les premiers m dans obs
- turbulence plus importante le jour/obs => réduite par un zo plus faible

Intercomparaison LES: champs de surface

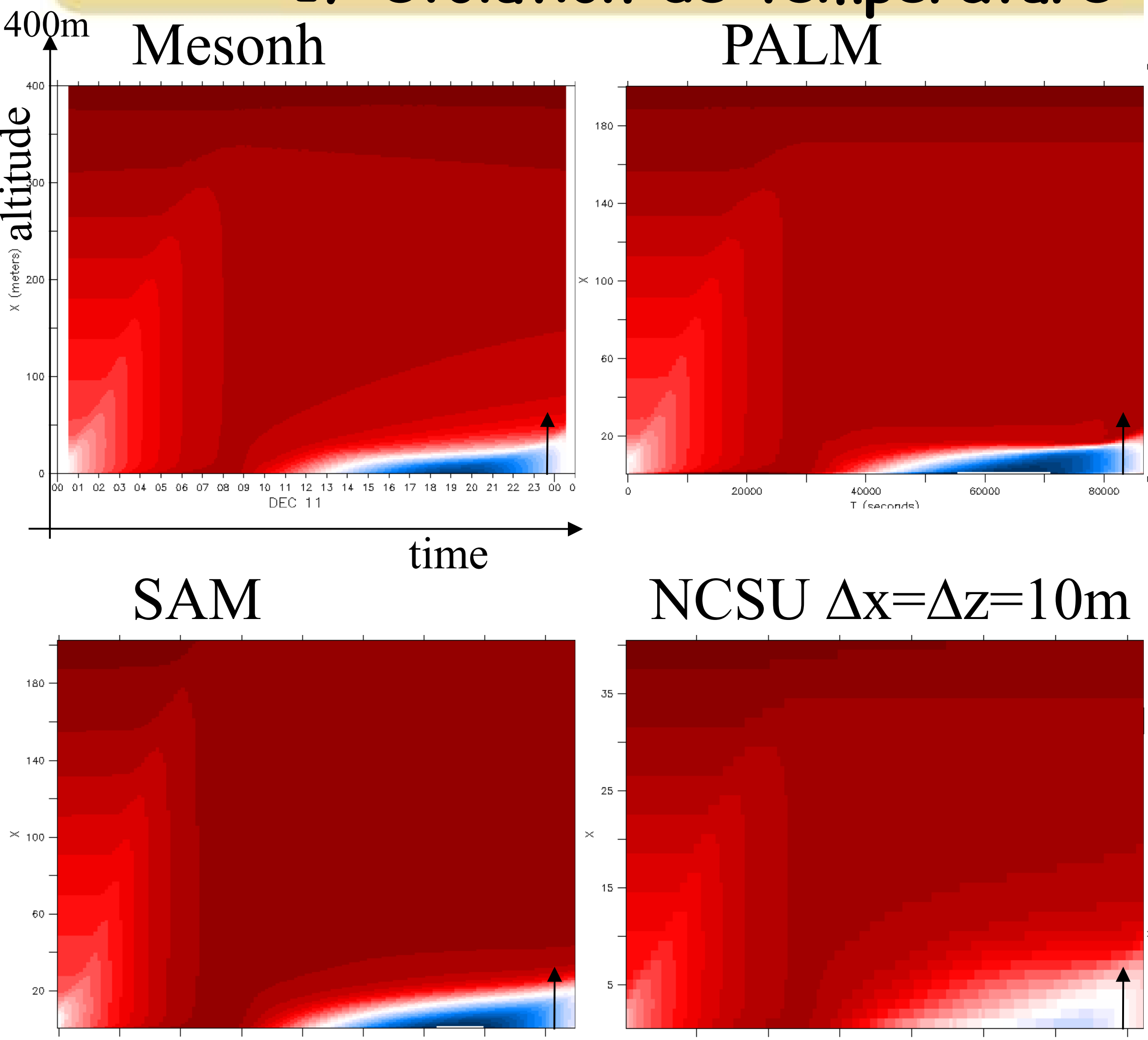


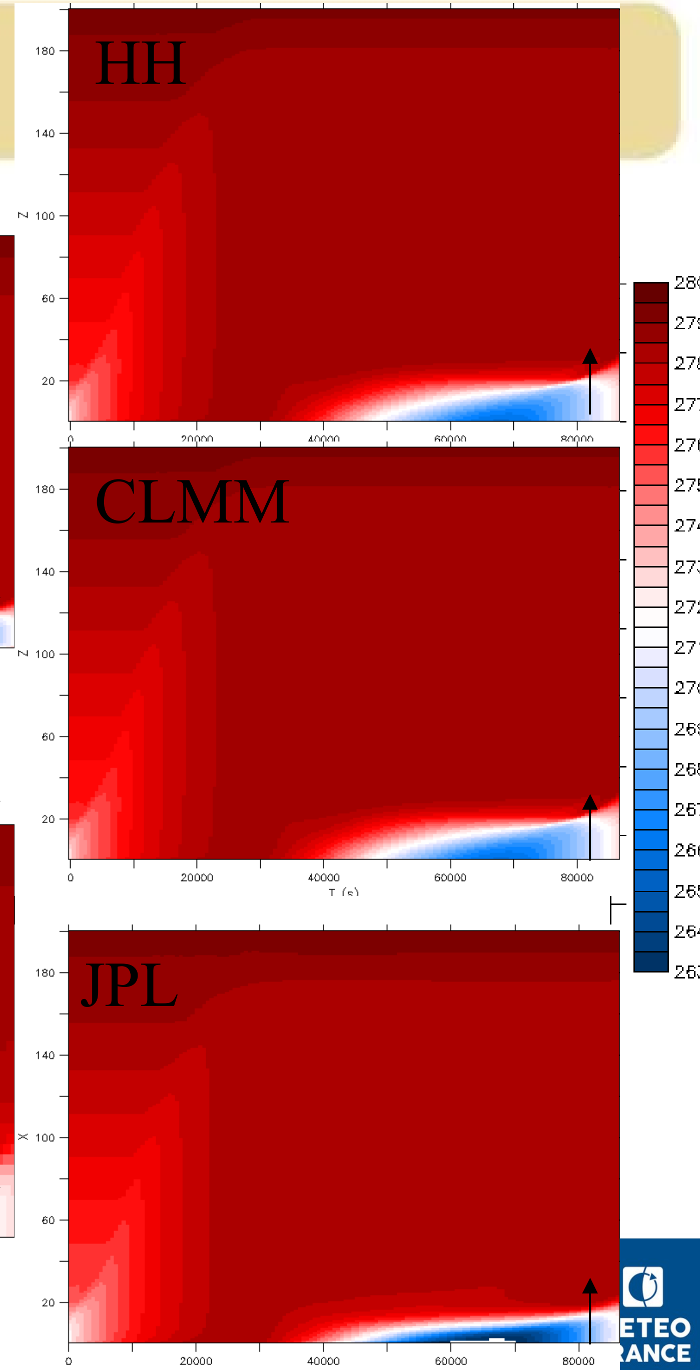
Forte variabilité de H entre Les simulations

Forte sensibilité à zo le jour

Surestimation de H, tke,u* meilleur accord pour zo=10^{-3}

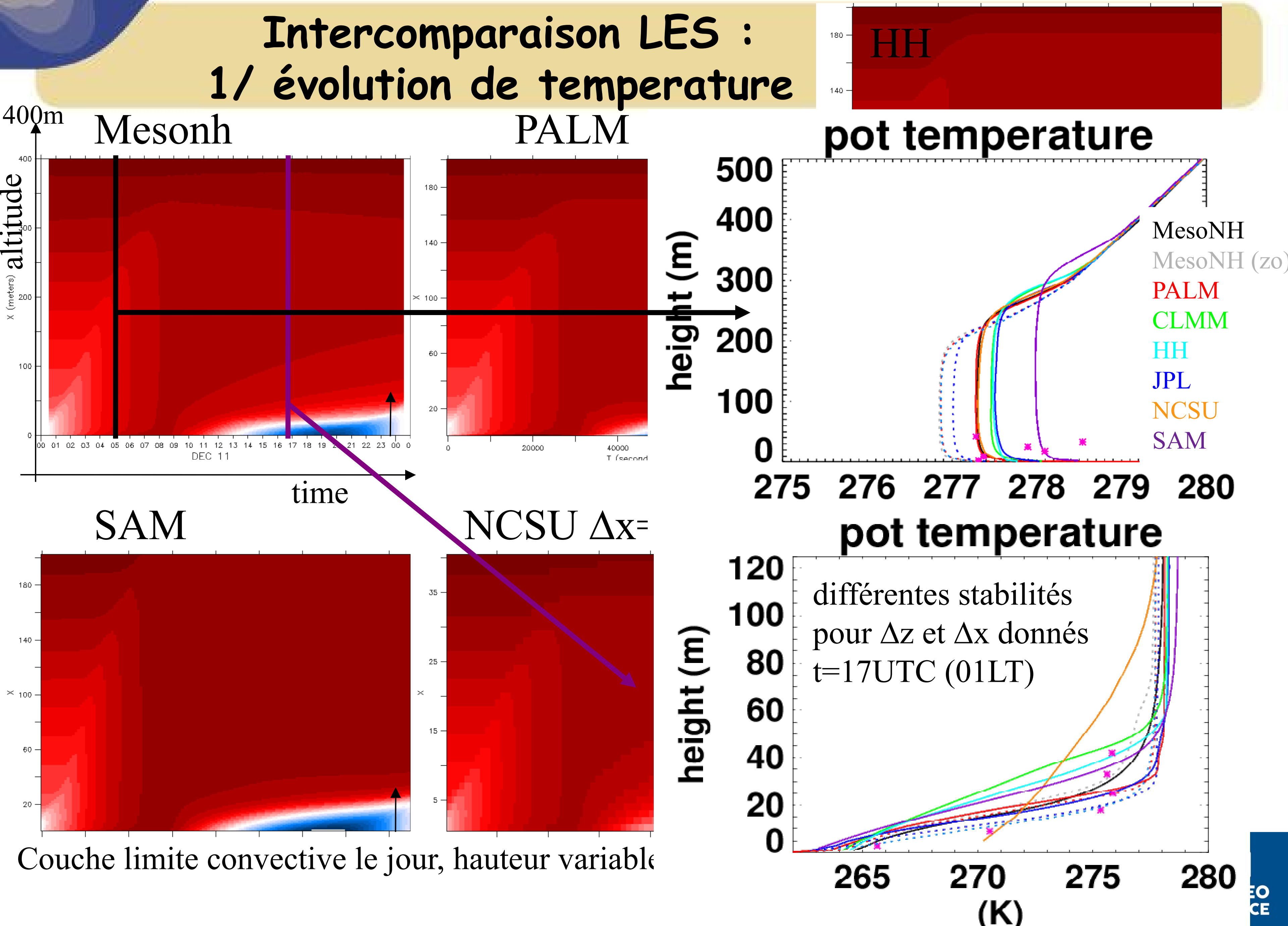
Intercomparaison LES :
1/ évolution de temperature





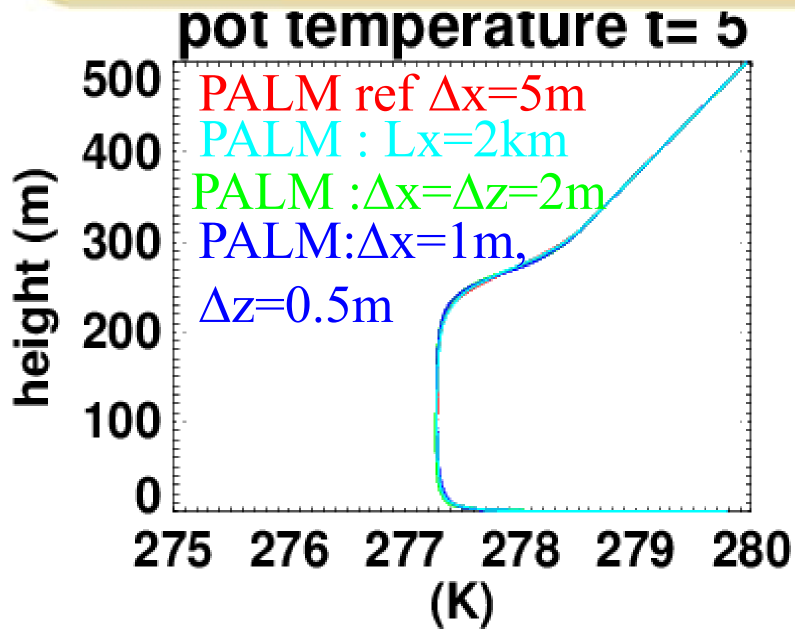
Couche limite convective le jour, hauteur variable la nuit

Intercomparaison LES :
1/ évolution de temperature



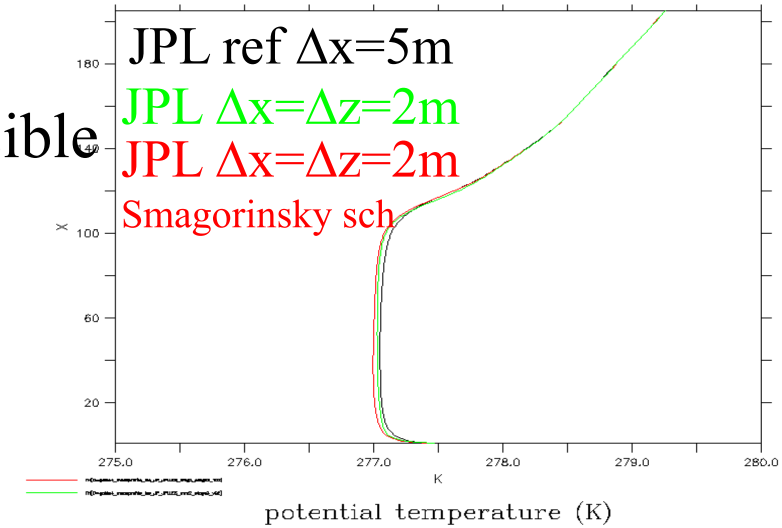
Couche limite convective le jour, hauteur variable

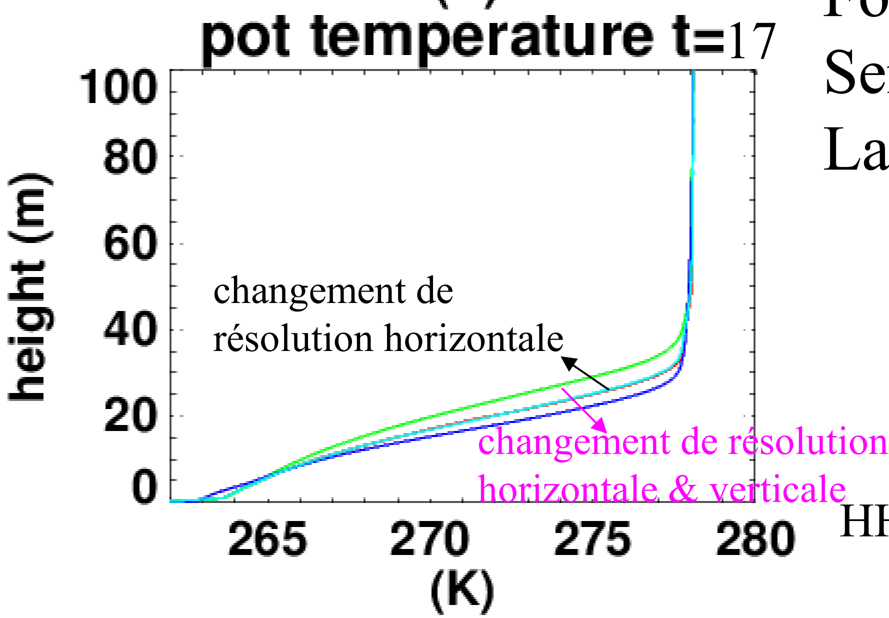
Sensibilité à la résolution : pour PALM & JPL



Peu sensible

En CBL

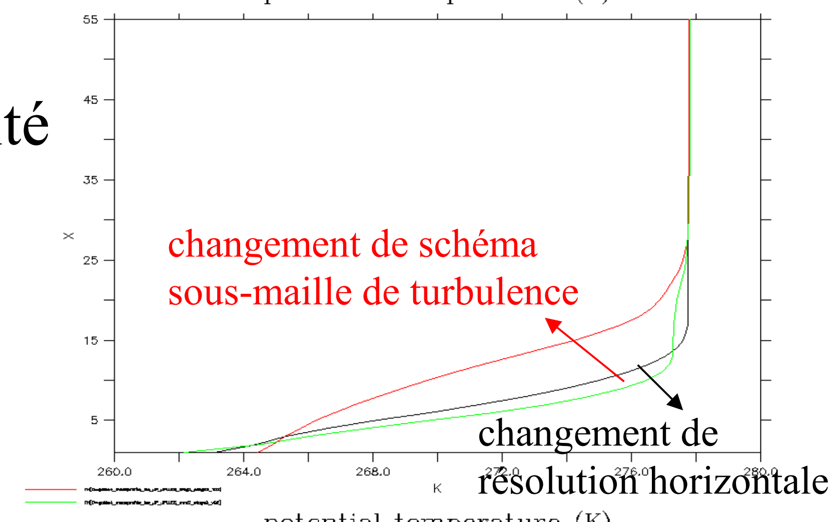




Forte

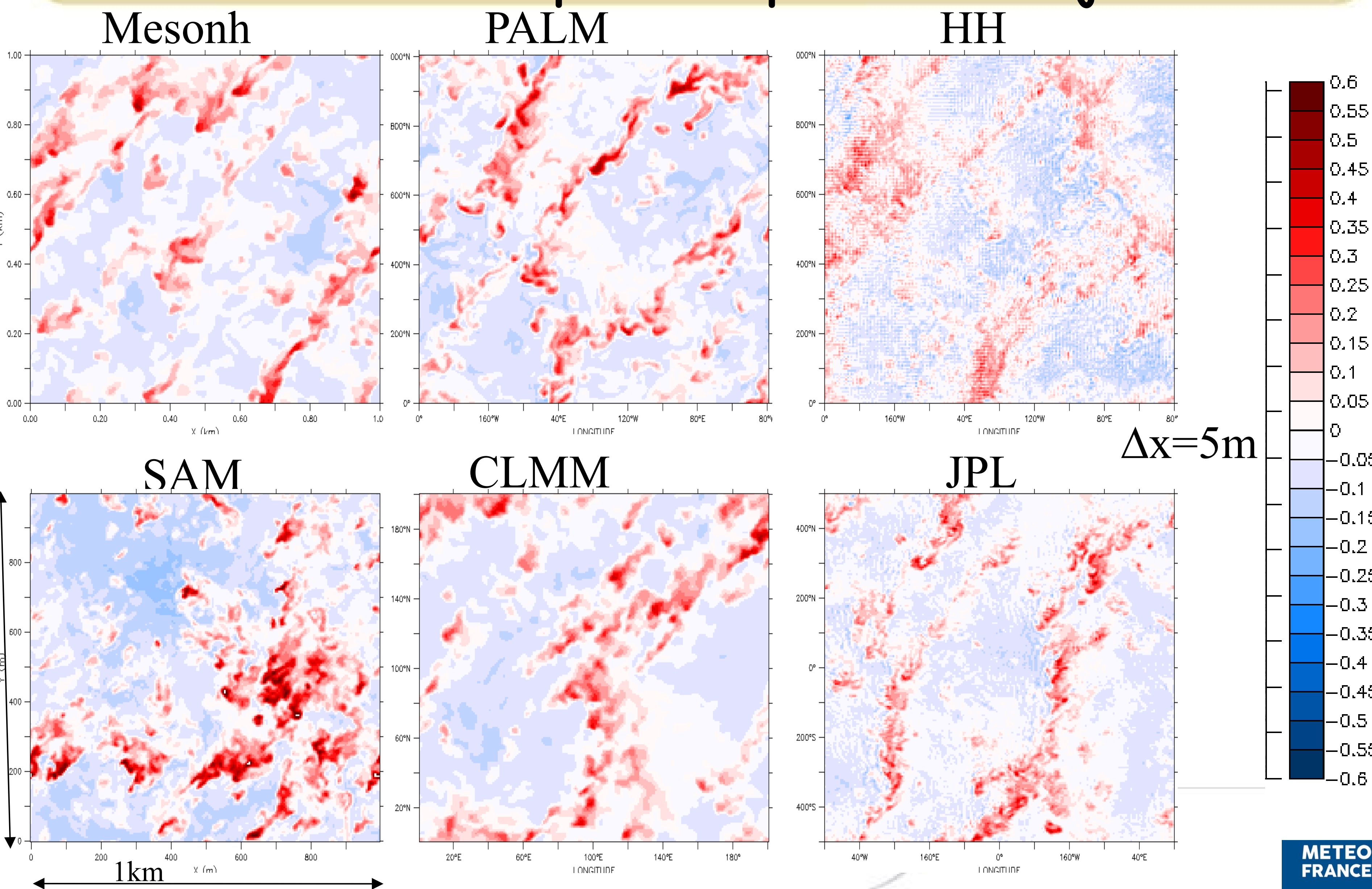
Sensibilité

La nuit



HHLES => 0.25m no convergence

intercomparaison LES : structures horizontales d'anomalies de température potentielle le jour à 39m



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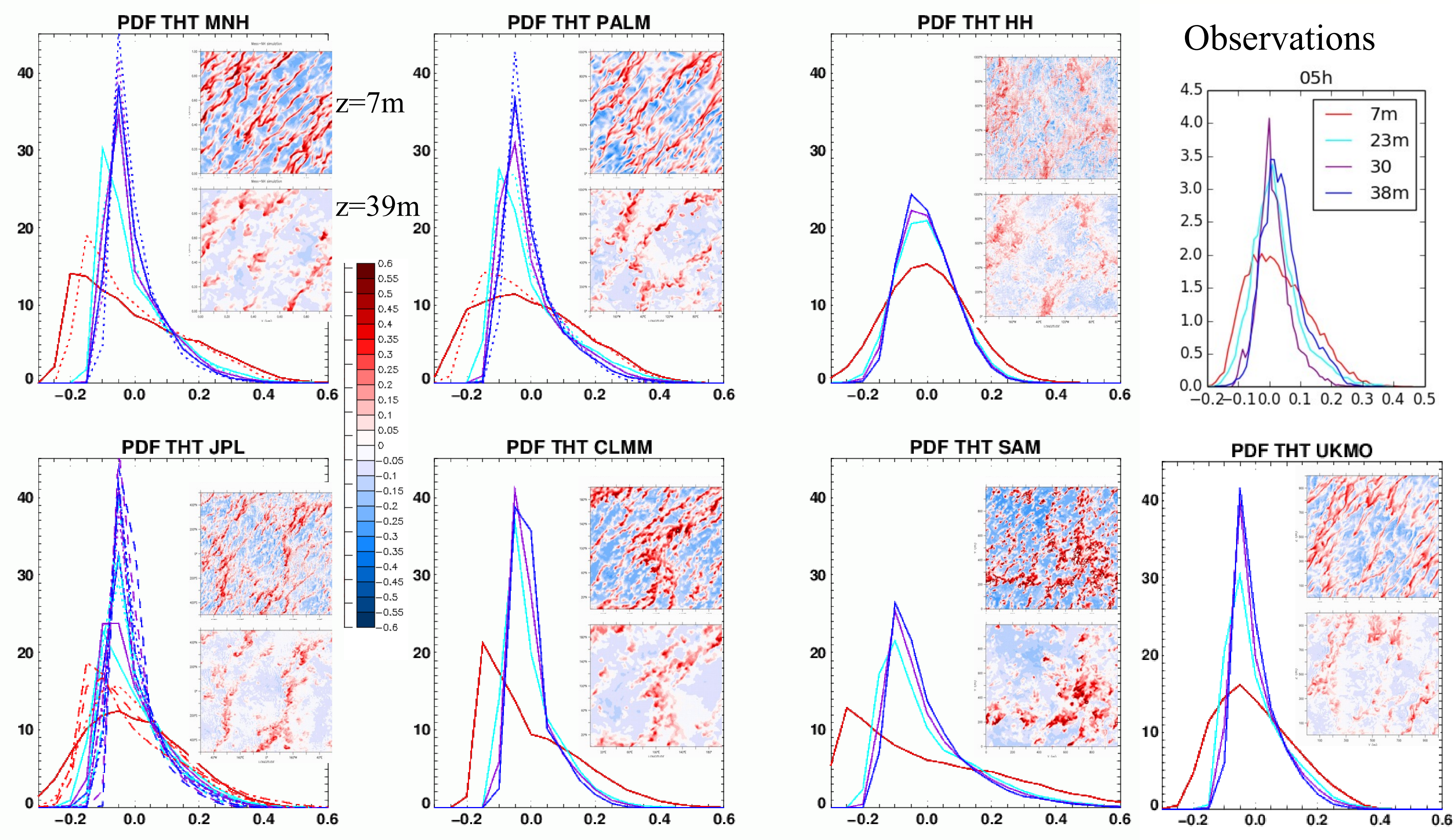
intercomparaison LES: distributions simulées/observées



Distribution plus ou moins skewnées

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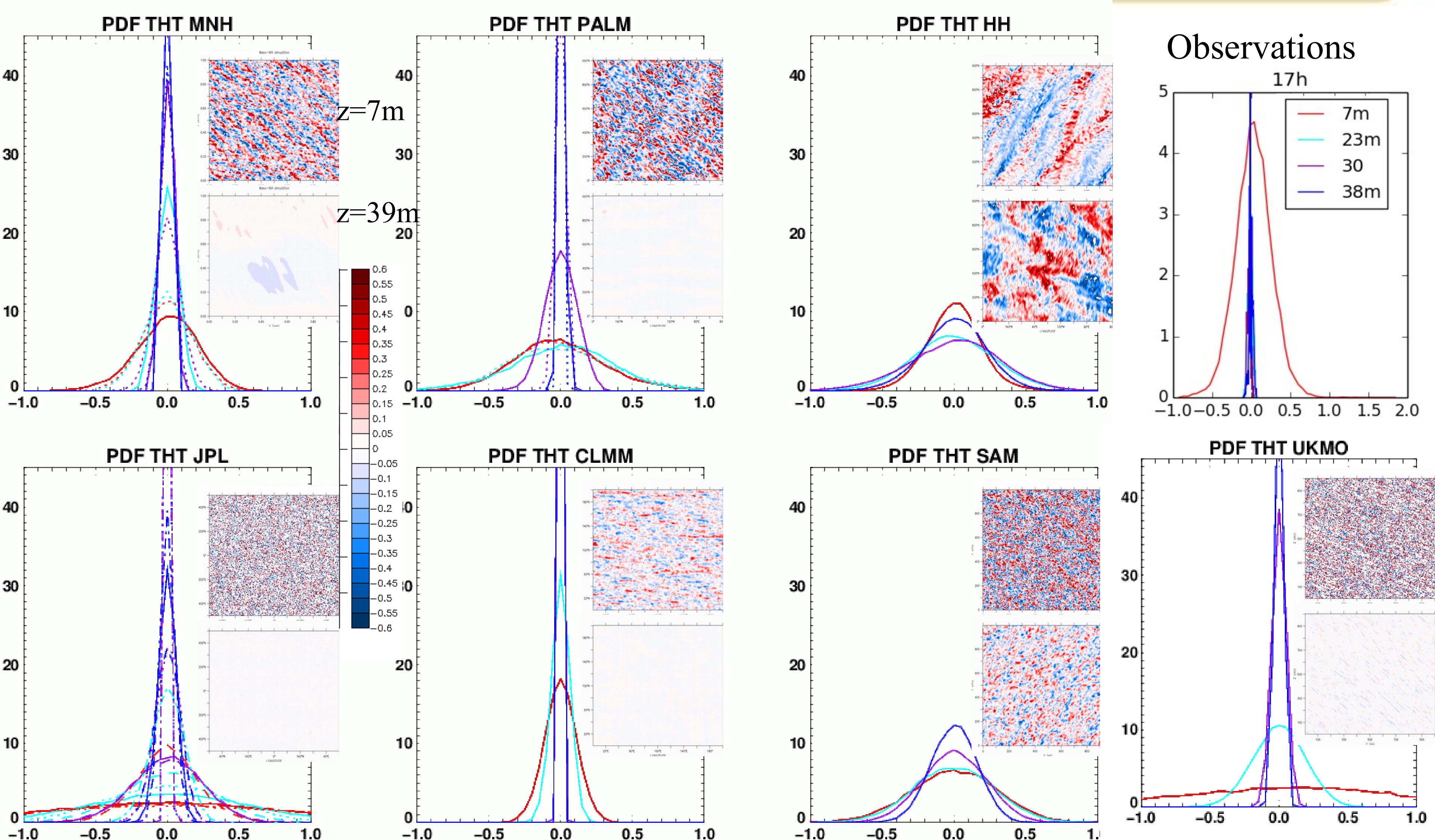
intercomparaison LES: distributions simulées/observées



Distributions symétriques
variabilités importantes entre modèles

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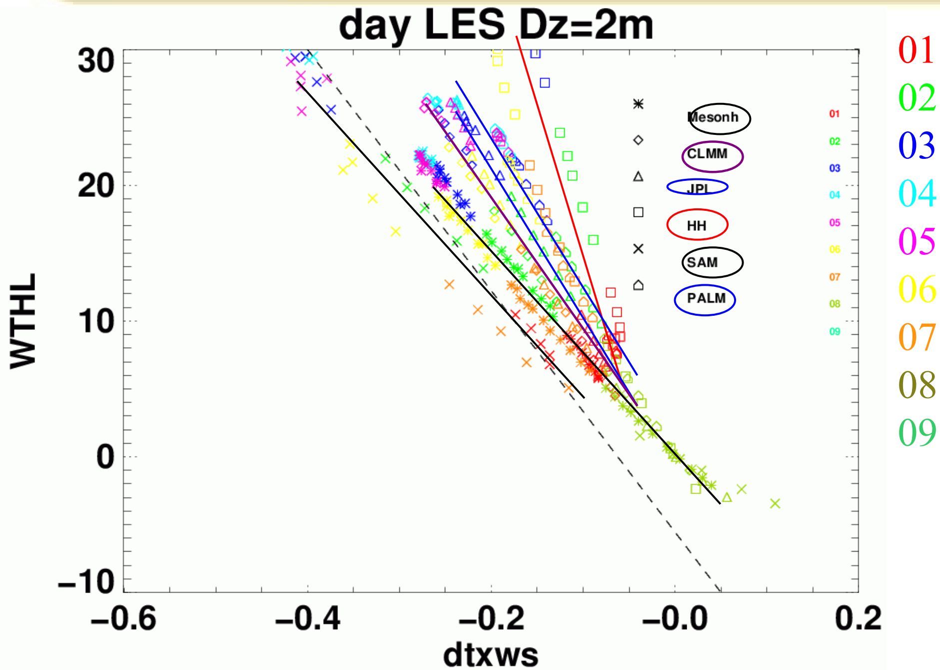
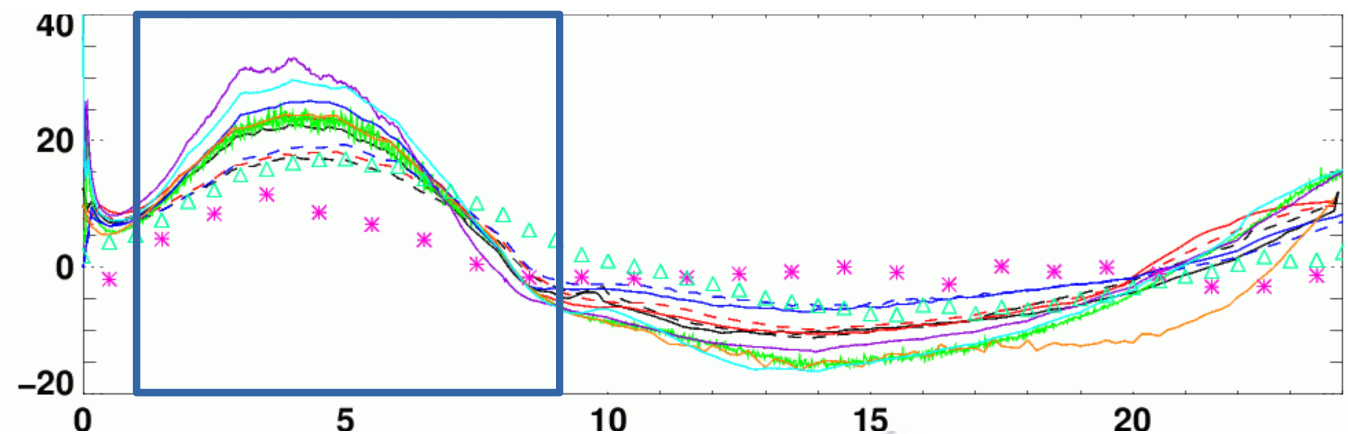
Coefficients de transfert chaleur le jour : <wthl>(z=2m)=f(Ws(z=3m)*Δth(1-3m))



- Pentes différentes entre les LES même si noyau dur



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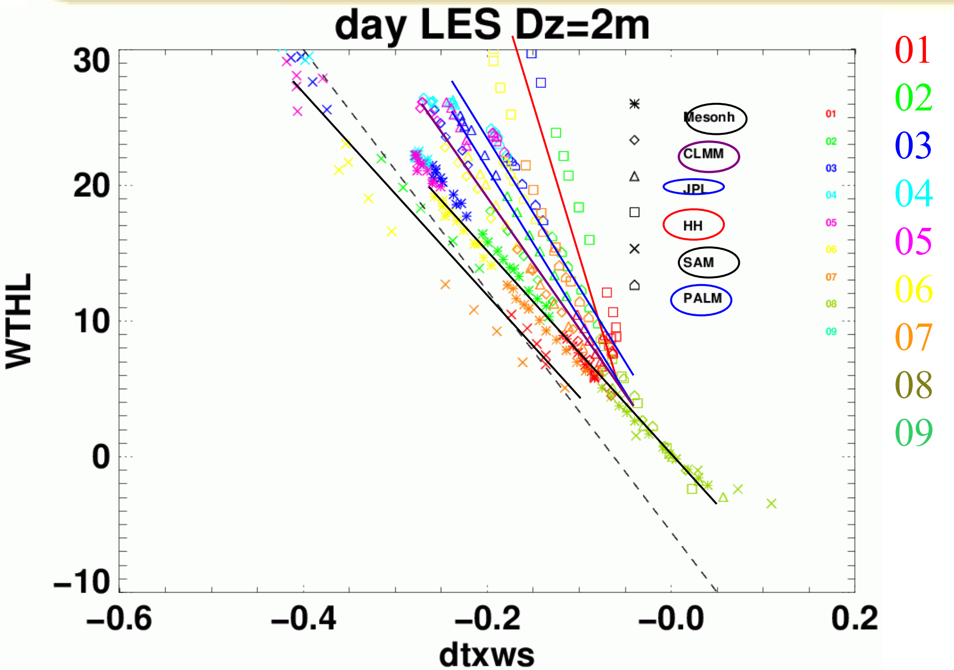
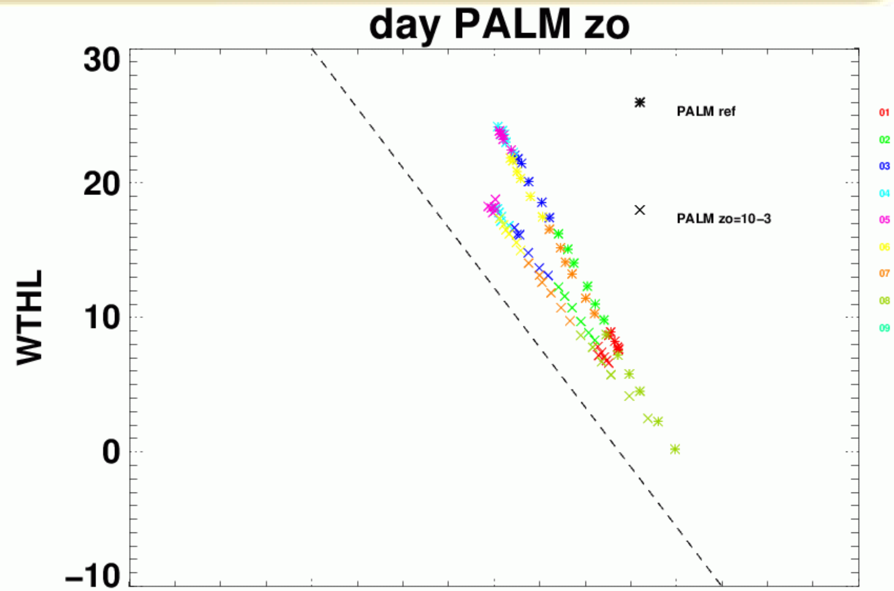
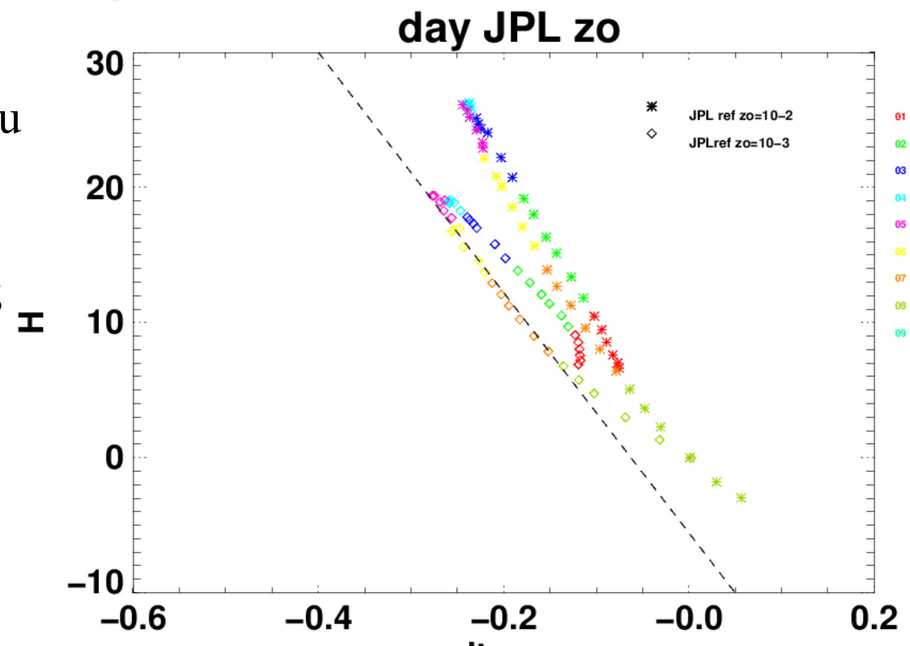
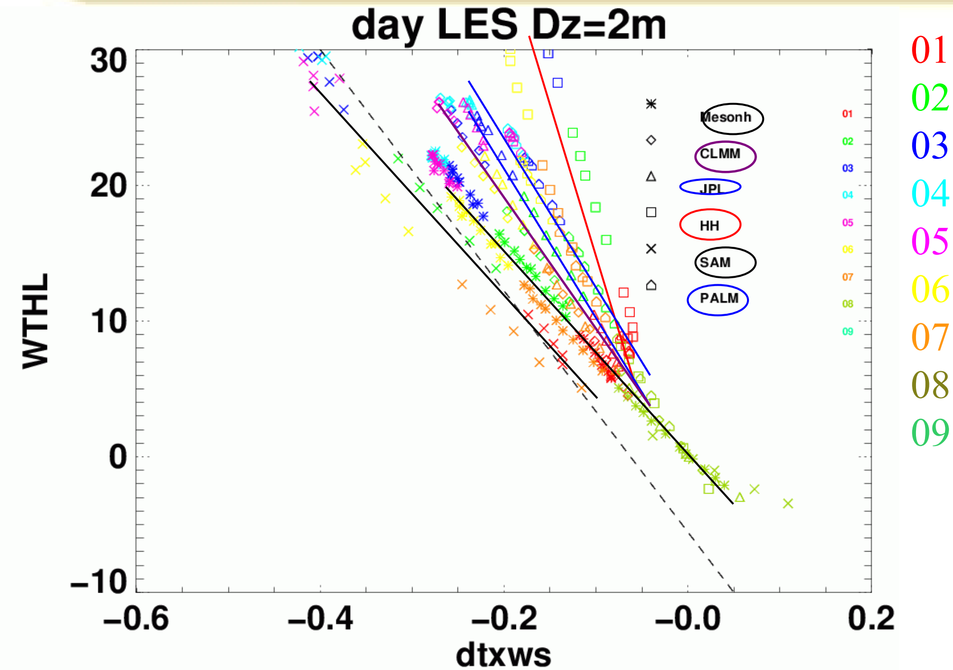


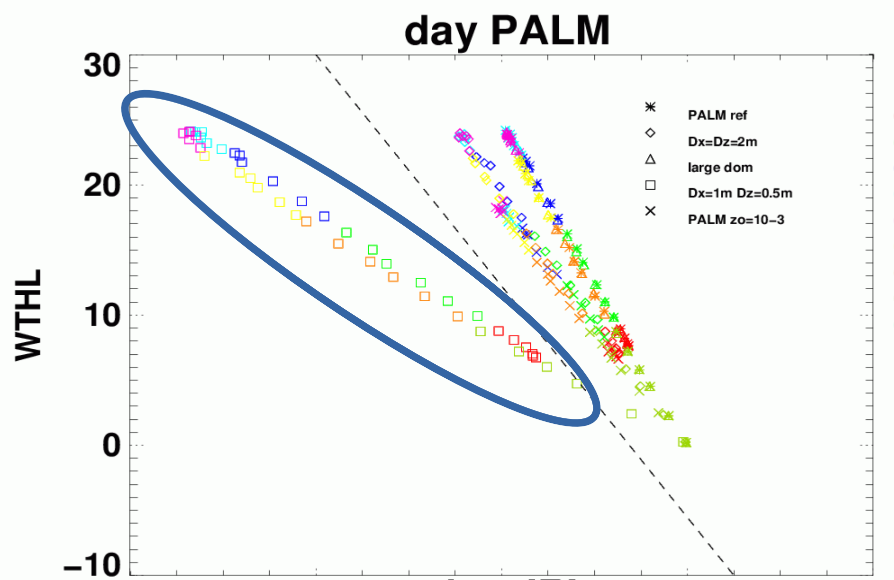


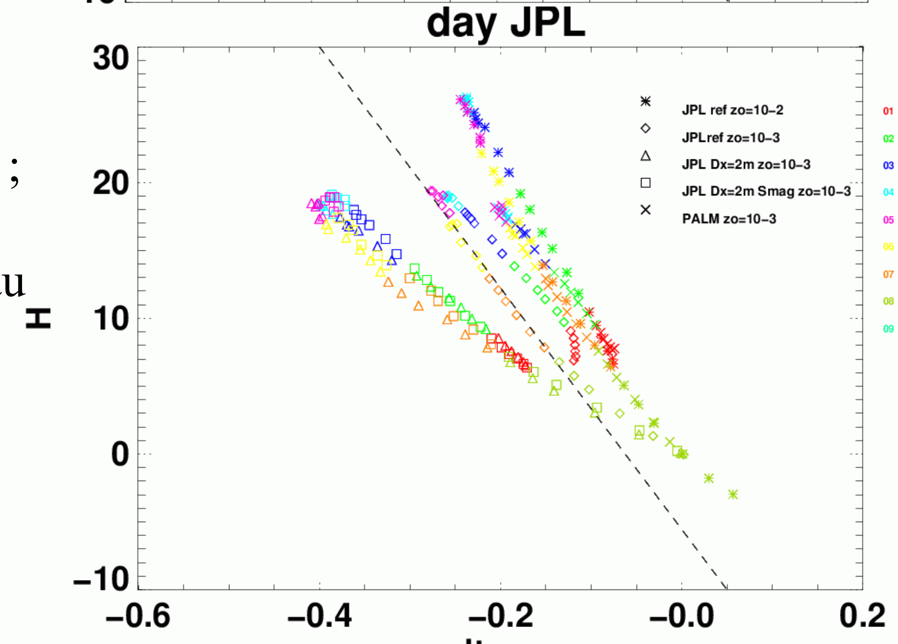


- Pentes différentes entre les LES même si noyau dur
- Sensibilité à la résolution (ver/hor) même si gradient calculé entre mêmes altitudes absolues ; peu sensible à zo

Coefficients de transfert chaleur le jour : <wthl>(z=2m)=f(Ws(z=3m)*Δth(1-3m))

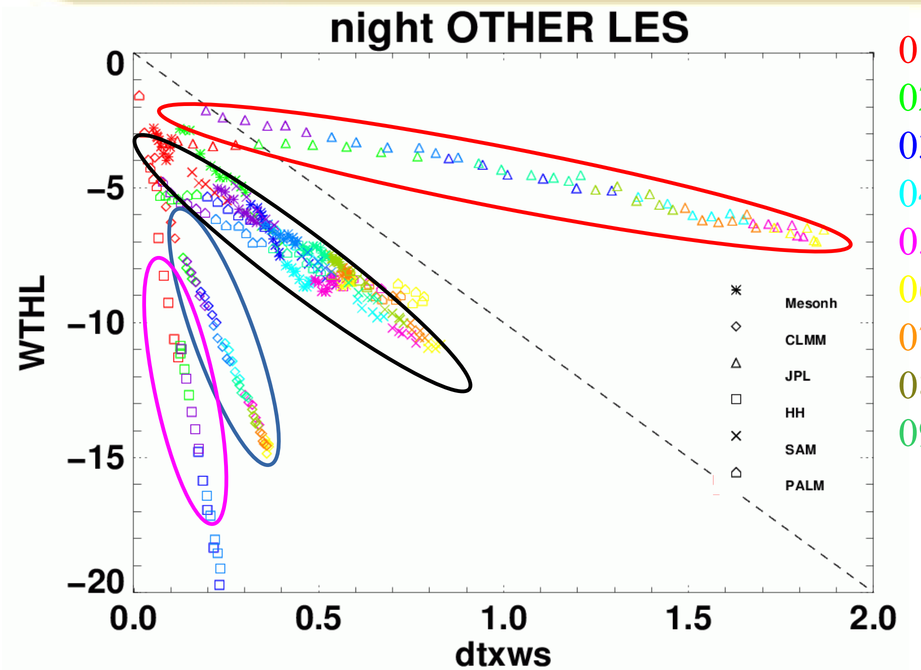


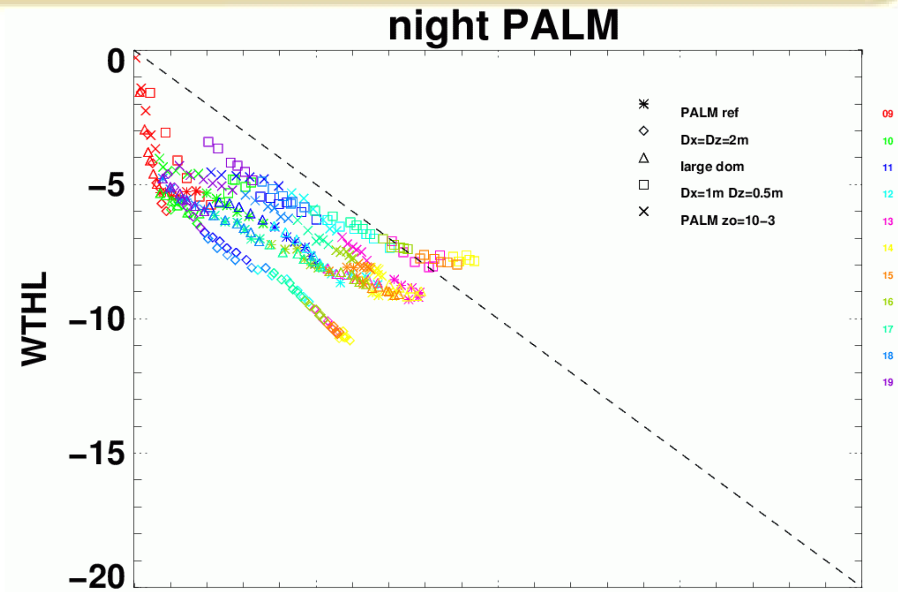


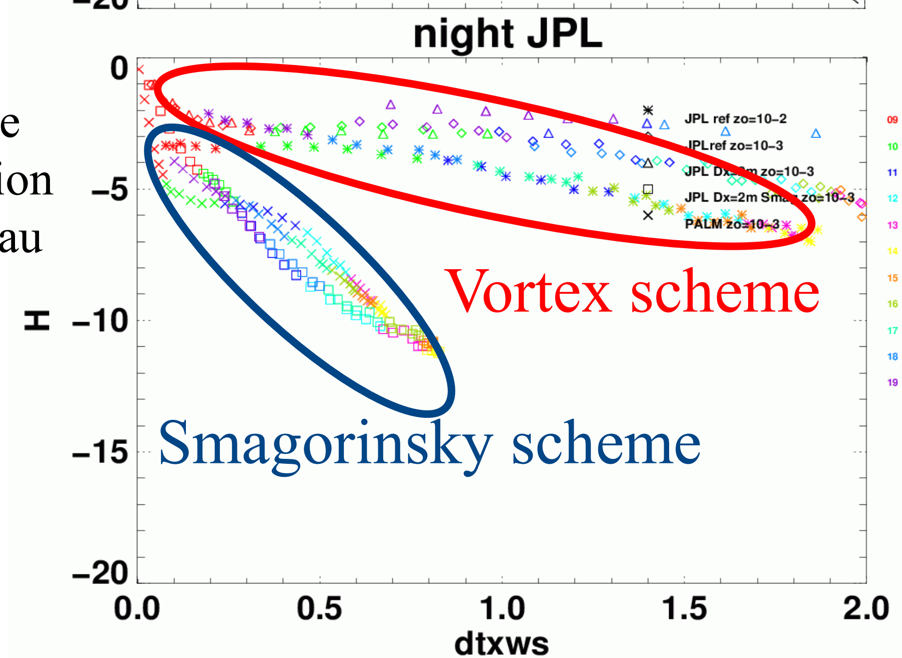


- Sensibilité à la résolution (ver/hor) même si gradient calculé entre mêmes altitudes absolues ; peu sensible à zo
- Pentes différentes entre les LES même si noyau dur

Coefficients de transfert chaleur la nuit : <wthl>(z=2m)=f(Ws(z=3m)*Δth(1-3m))

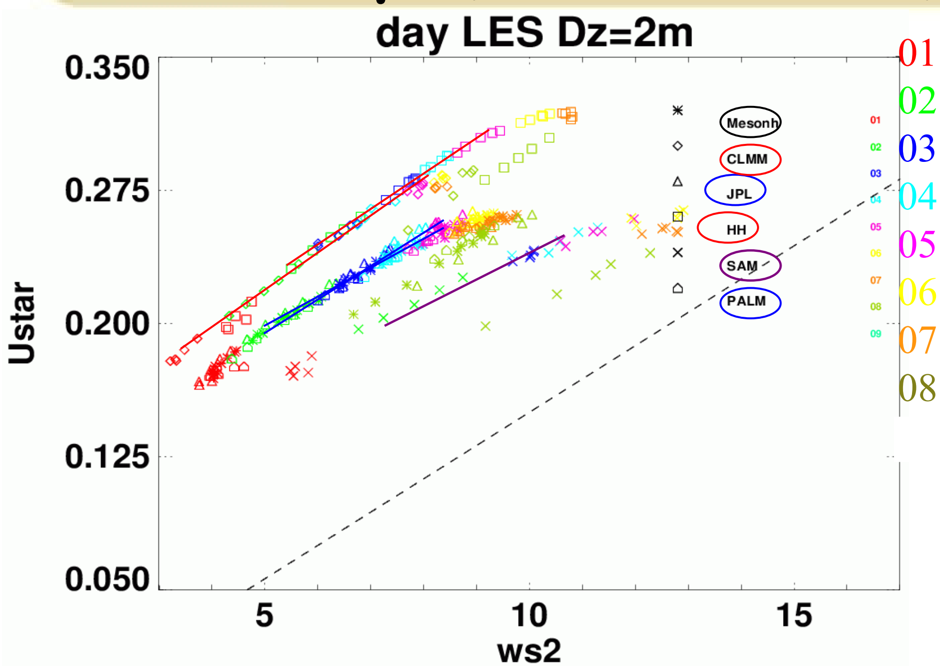


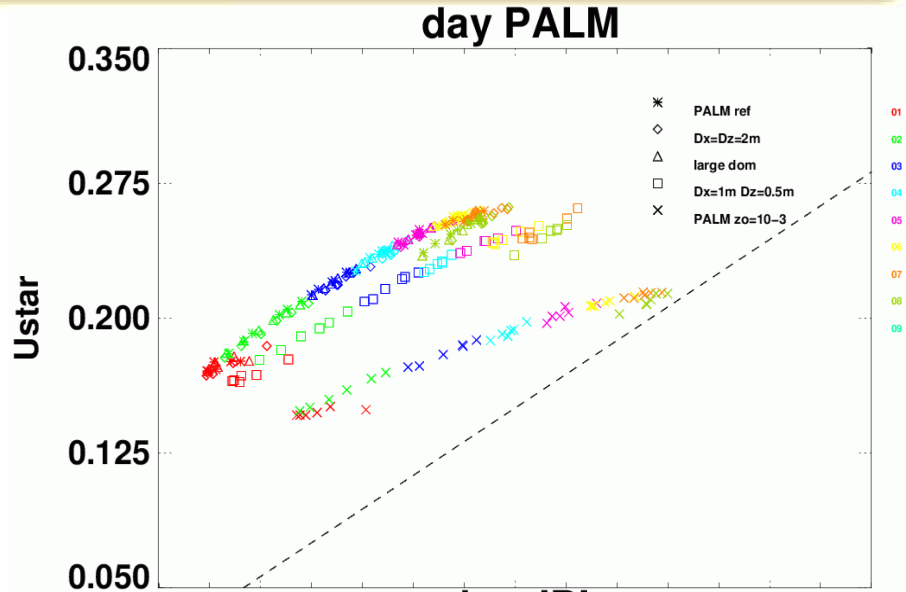


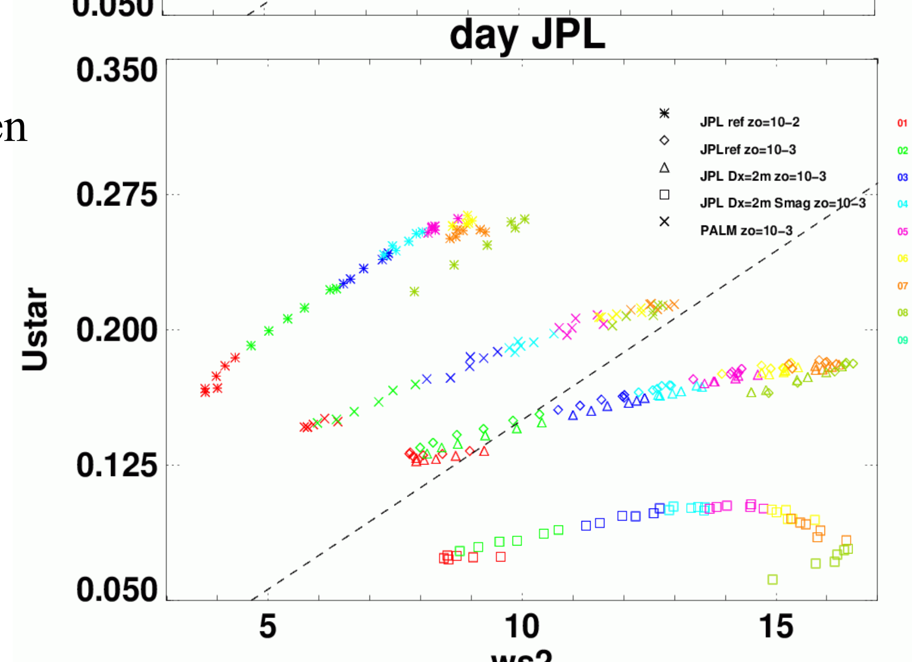


- JPL : forte sensibilité au schéma de turbulence
- Relativement faible sensibilité à zo et résolution
- Pentes différentes entre les LES même si noyau dur

Coefficients de transfert moment le jour : sqrt(<wu>²+<wv>²)(z=2m)=f(Ws(z=3m)²)

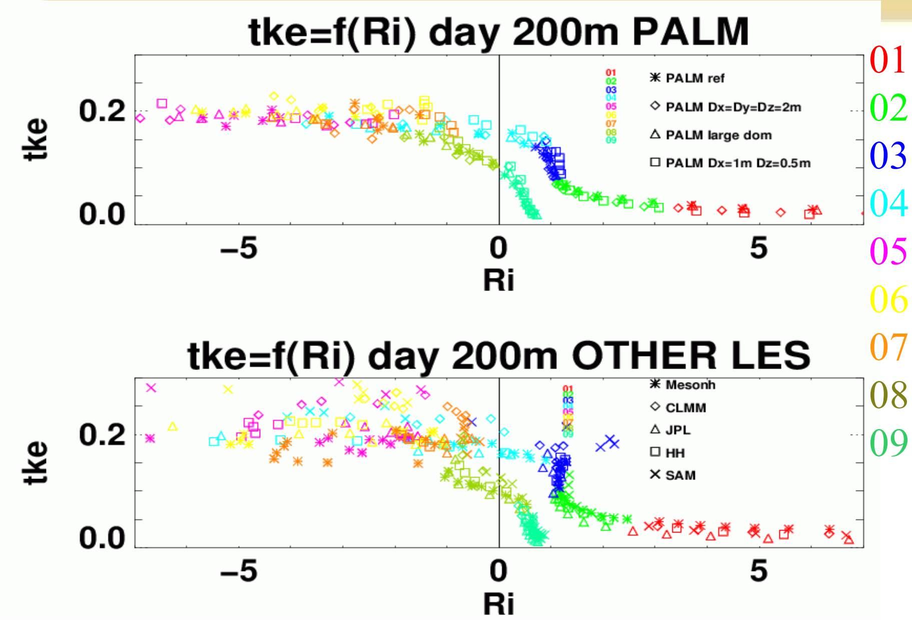






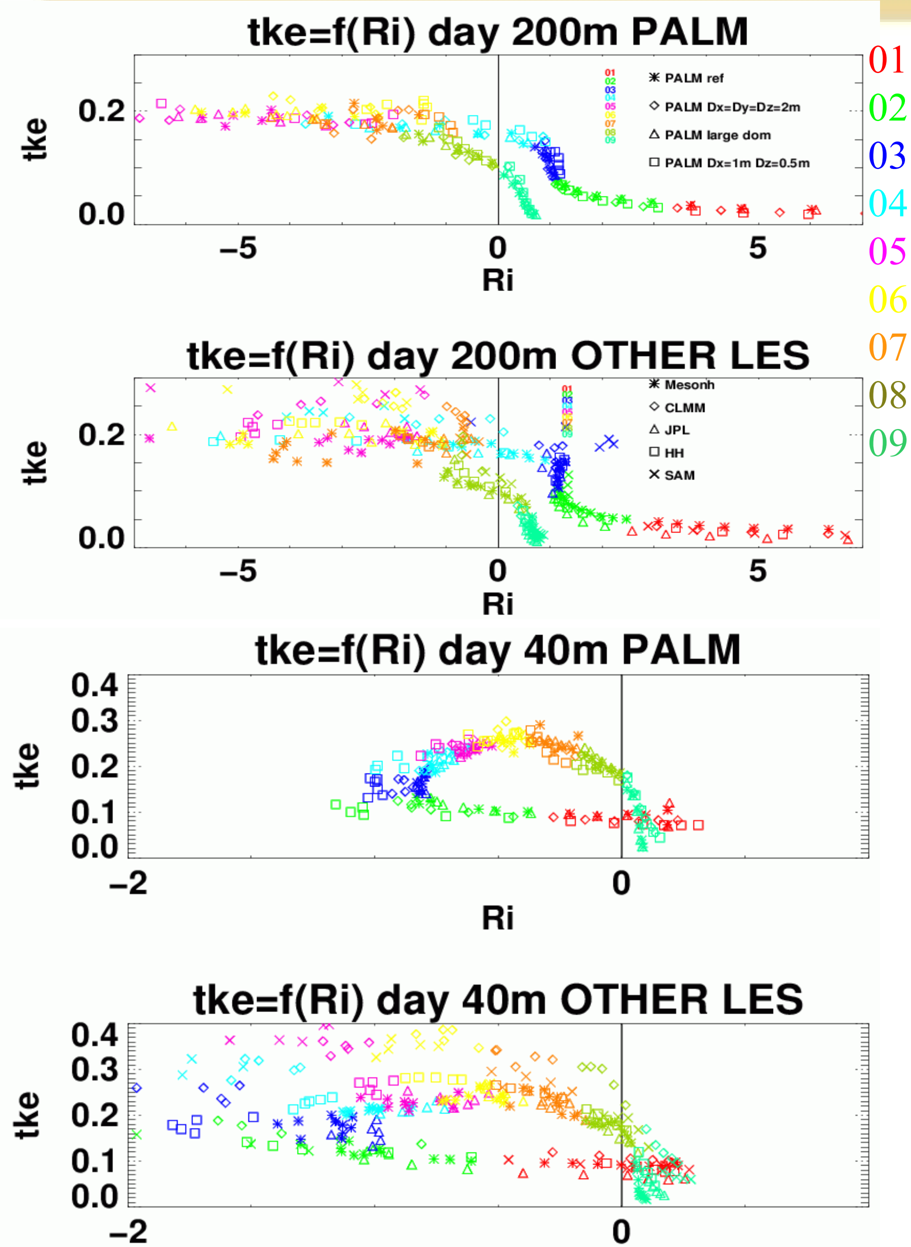
- Sensibilité à zo et au schéma de turbulence; bien moins sensible à la résolution (ver/hor)
- Pentes bien plus proches entre les LES

Régimes turbulents : en fonction des LES



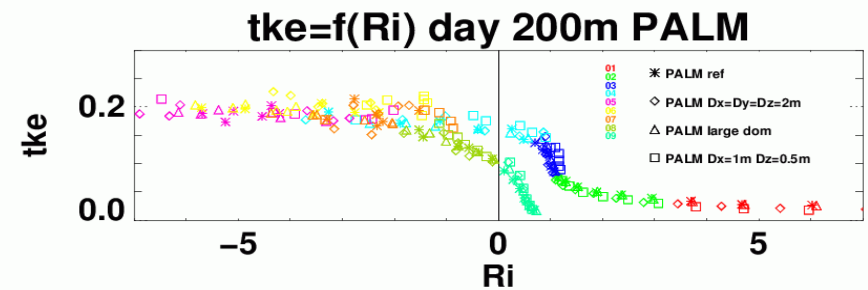
Le jour : histérésie à 200m

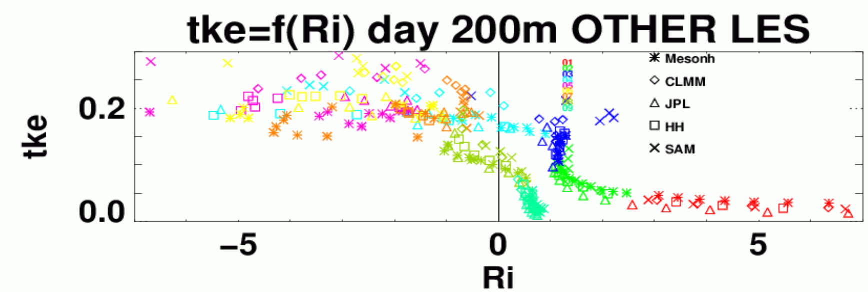
Régimes turbulents : en fonction des LES



Le jour : histérésie à 200m & 40m : + ou – accord Entre les modèles

Régimes turbulents : en fonction des LES





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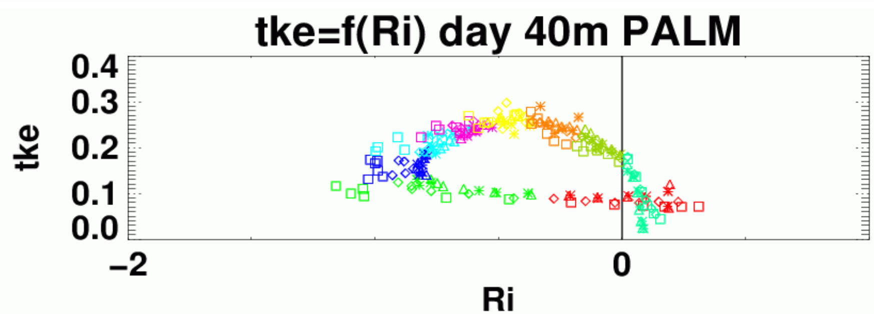
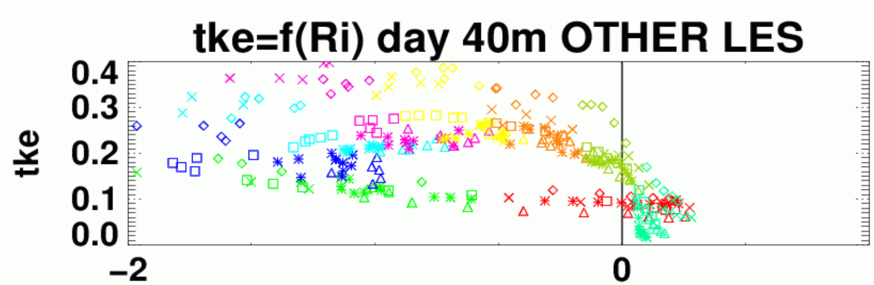
Le jour : histérésie à 200m & 40m : + ou – accord
Entre les modèles

Plus de différences la nuit, exploration de Ri ± fort





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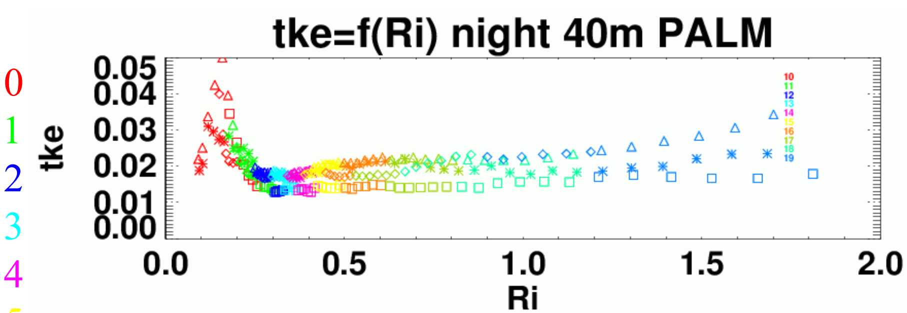

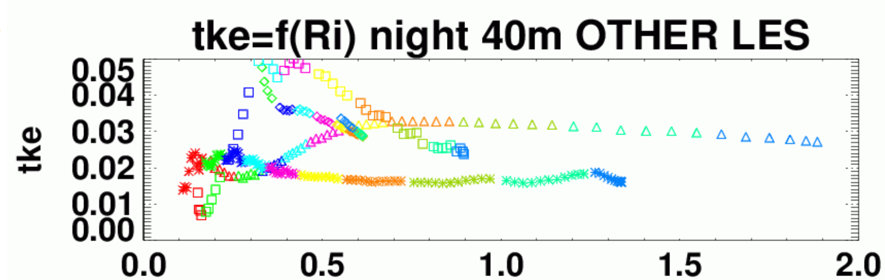

Conclusions & Perspectives

- Sensibilité à la résolution verticale & horizontale surtt la nuit
Pas de convergence (PALM-> 1m, JPL → 2m, HHLES → 0.25m)
La nuit, tout se passe dans les 60m => très fine res°
→ besoin de définir un autre setup : restart à 0830 pour un petit domaine et plus fine résolution(tests avec HHLES → 0.25m)

- Stage 3 (setup simplifié) très proche des setup + réaliste (Stage 2): - bon accord avec les observations de la tour

- Différences importantes entre LES en termes de flux de surface, de distributions horizontales, de spectres,... : peut-on relier ces différences à des différences de schémas de turbulence?
→ en cours...

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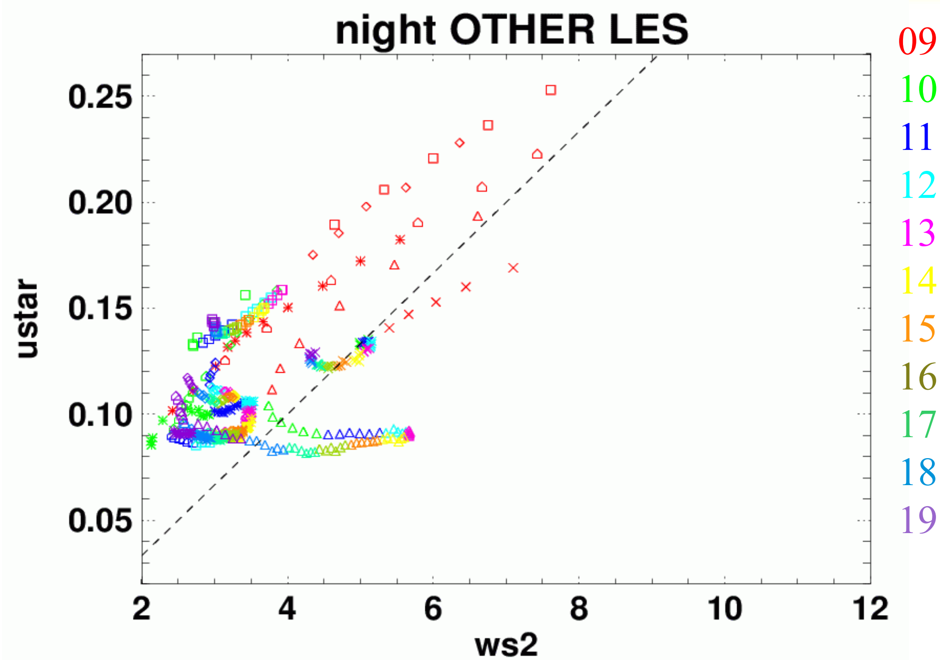
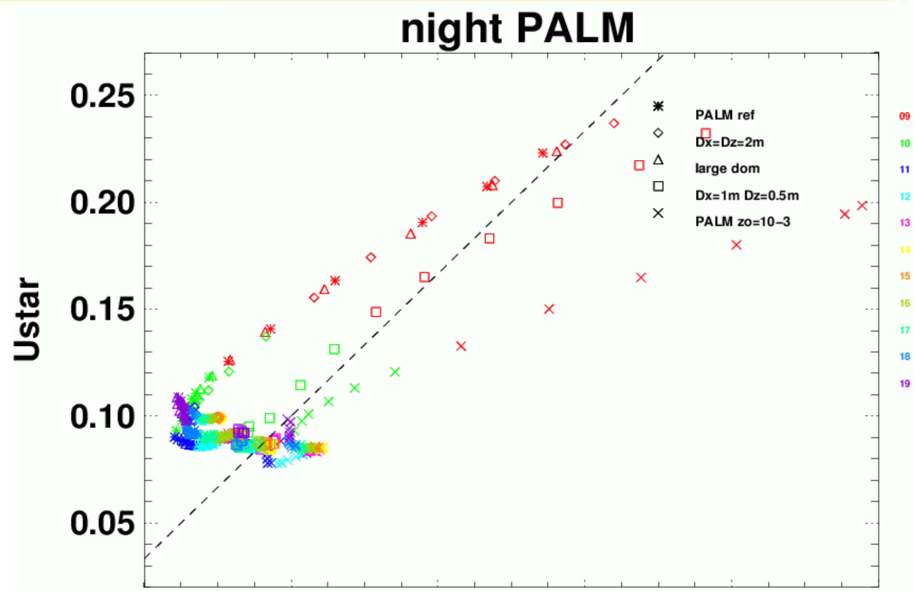
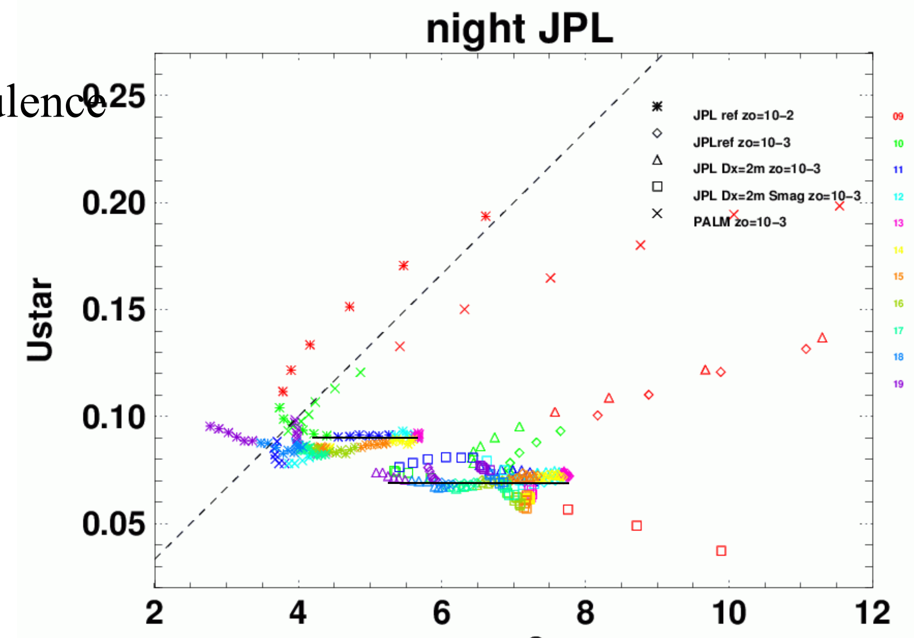
Coefficients de transfert moment la nuit: sqrt(<wu>^{2}+<wv>^{2}(z=3m)=f(Ws(z=3m)^2)





- Sensibilité surtout à zo et au schéma de turbulence
- Pentes différentes entre les LES



Acknowledgements

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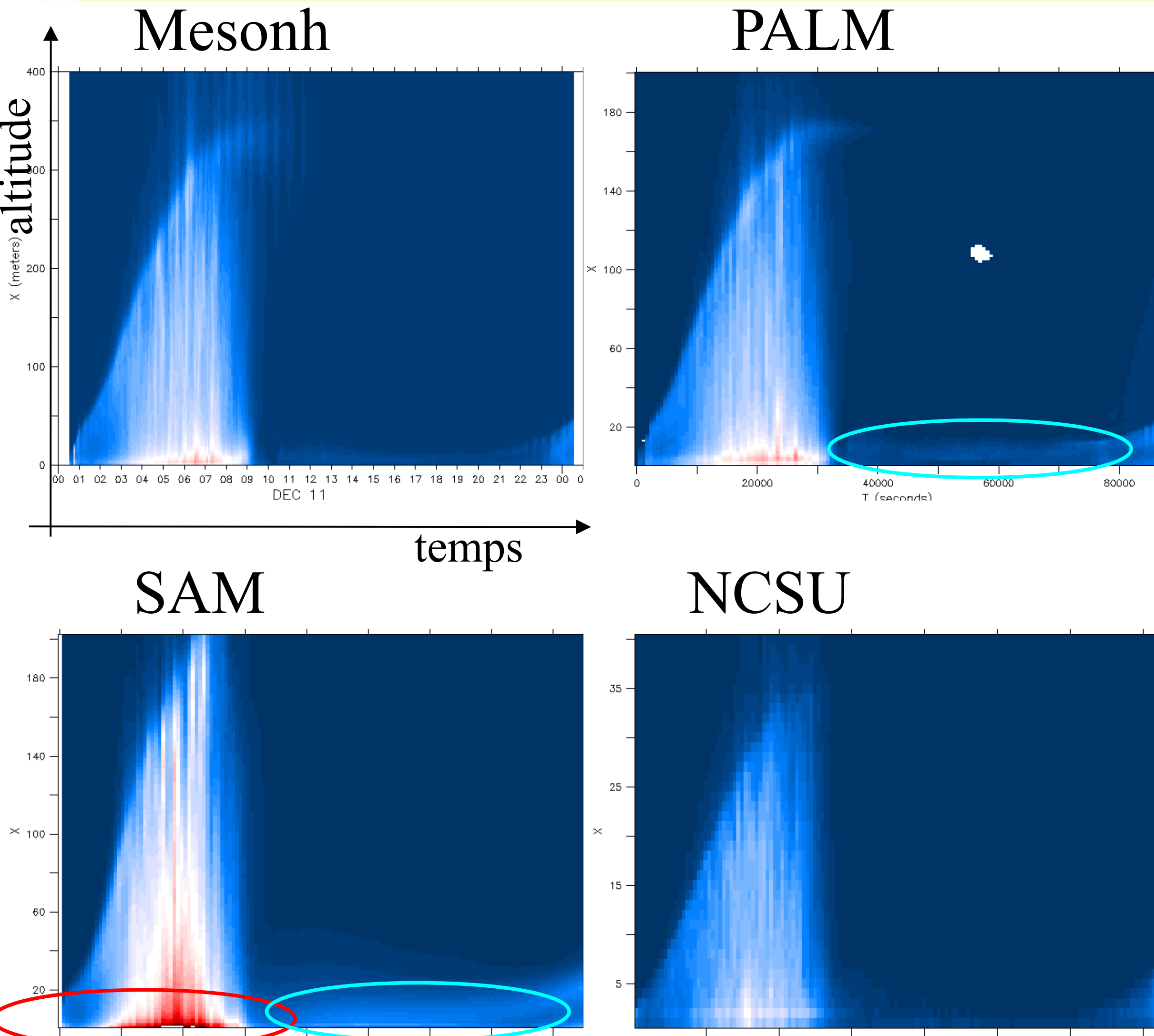
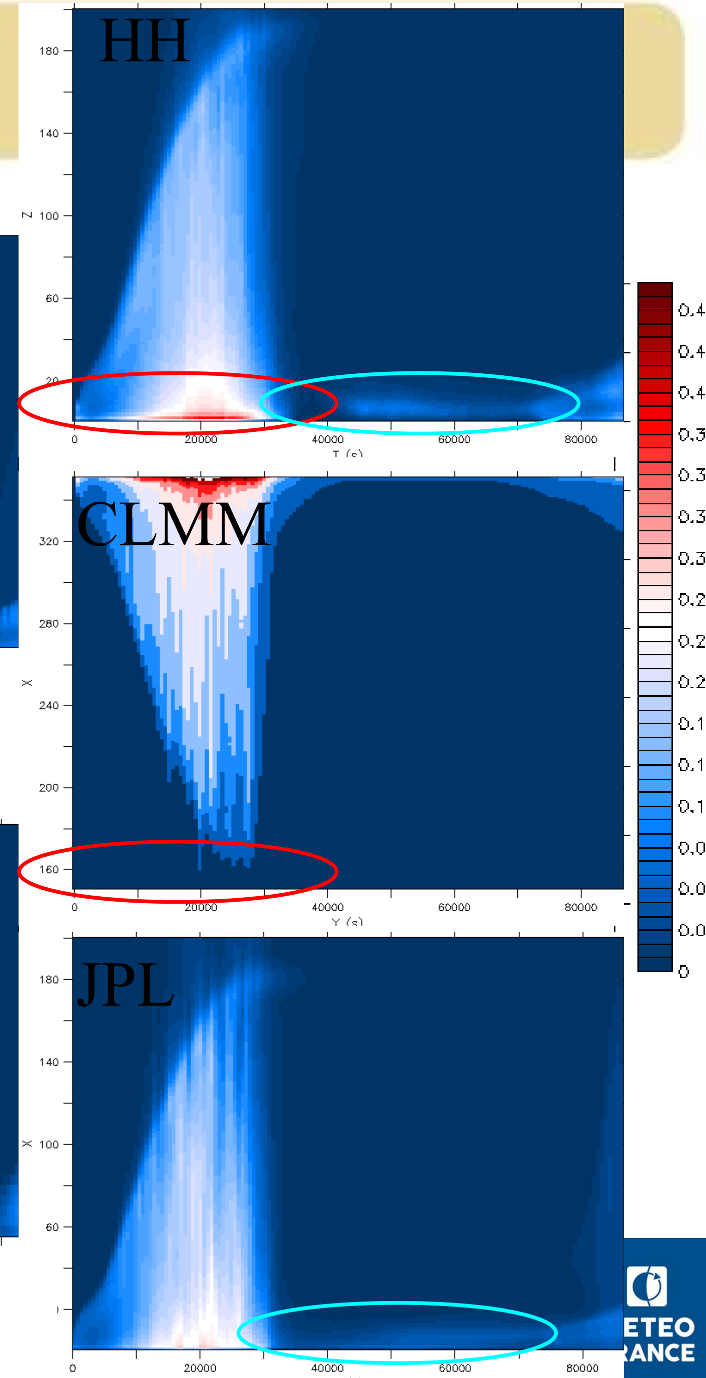
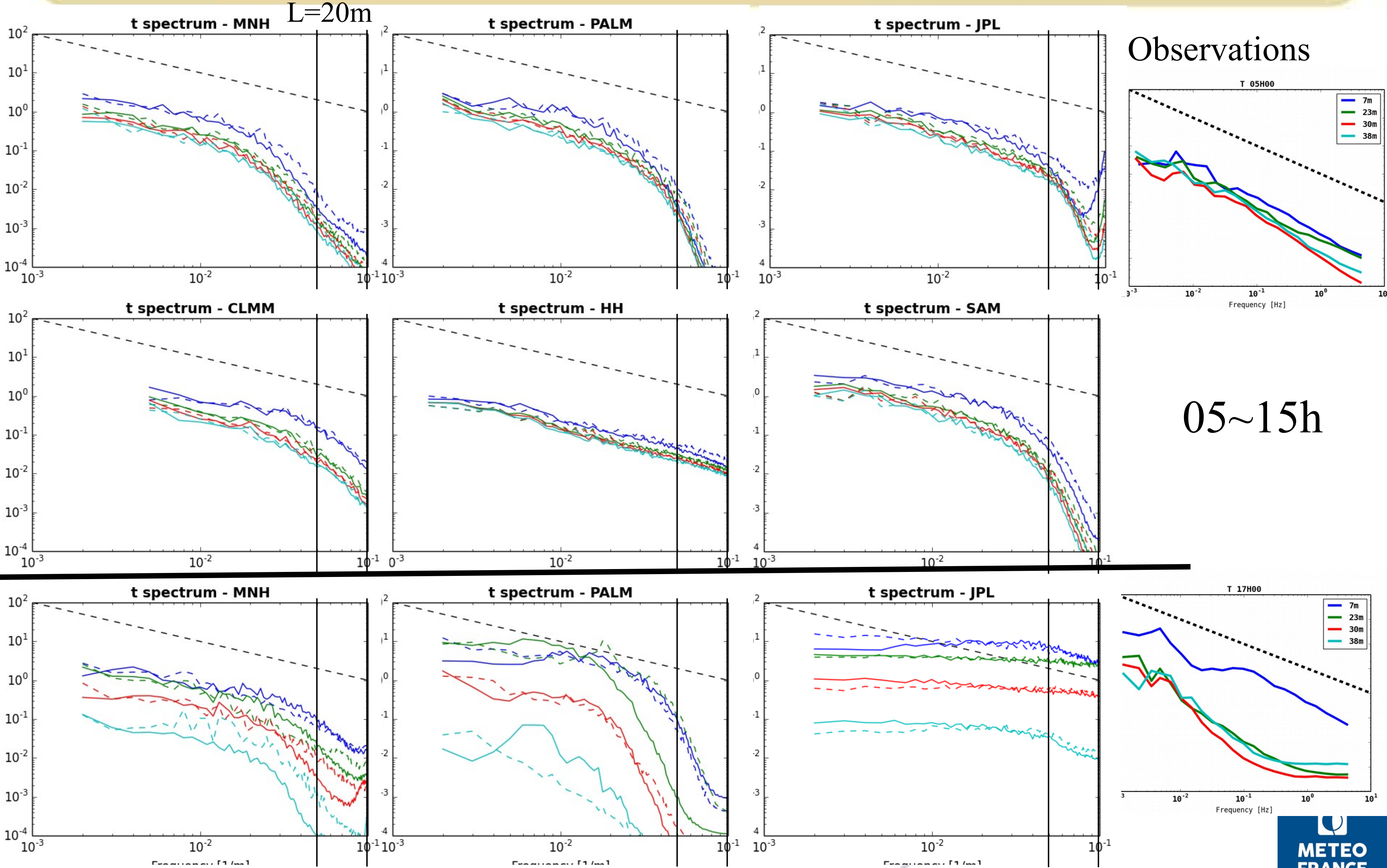
LES intercomparsion :
2/ turbulent kinetic energy evolution



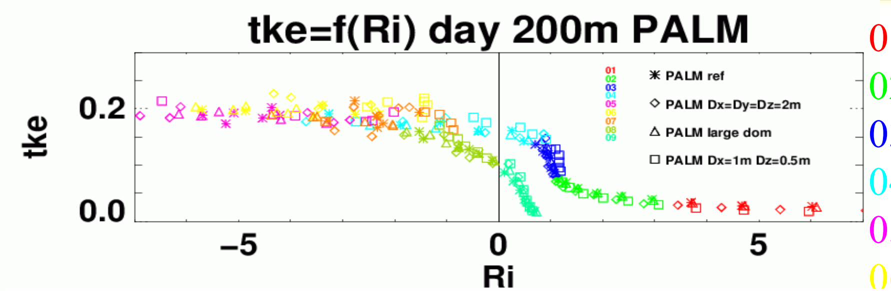


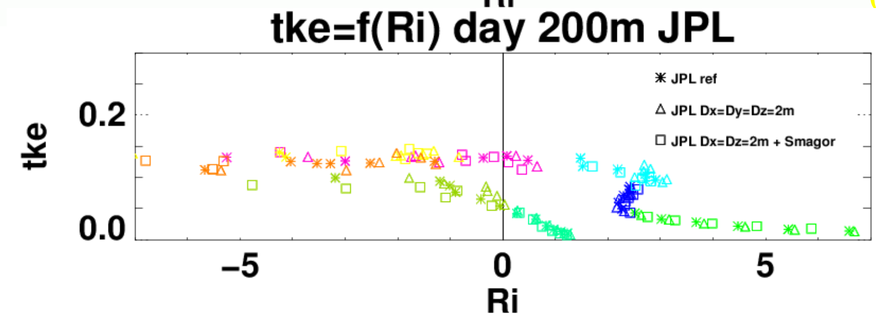
Larger daytime tke for SAM, CLMM and HH
Larger nighttime tke for SAM, PALM, HH, JPL

LES intercomparison : spectrum at observed levels



Turbulent regimes : resolution impact





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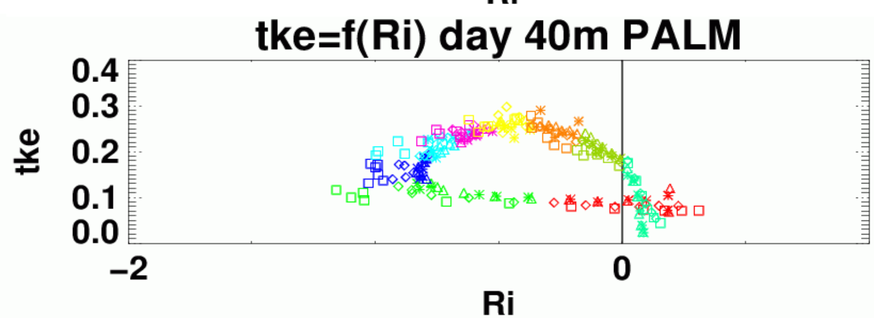
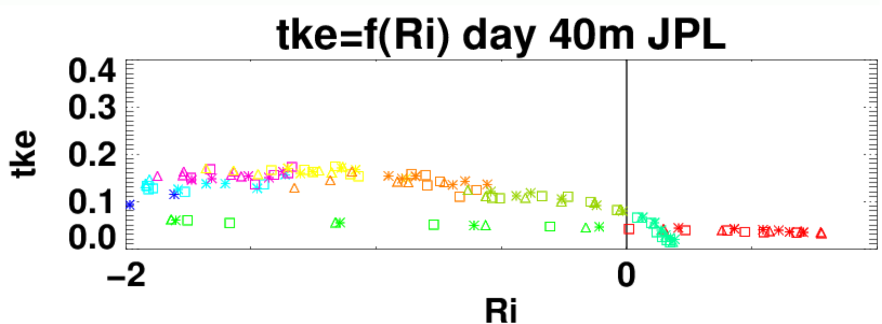
Daytime histeresis at 200m and 40m : more or less agreement between models

Larger differences at night, LES can more or less Explore large Ri





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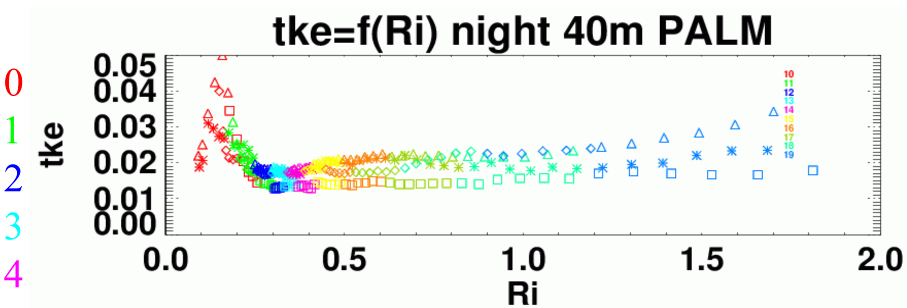
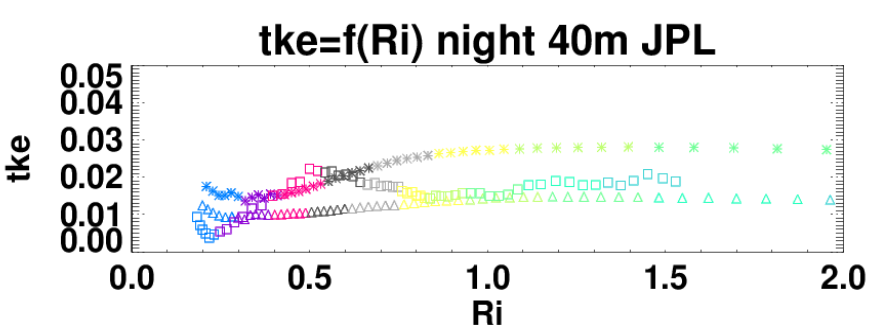
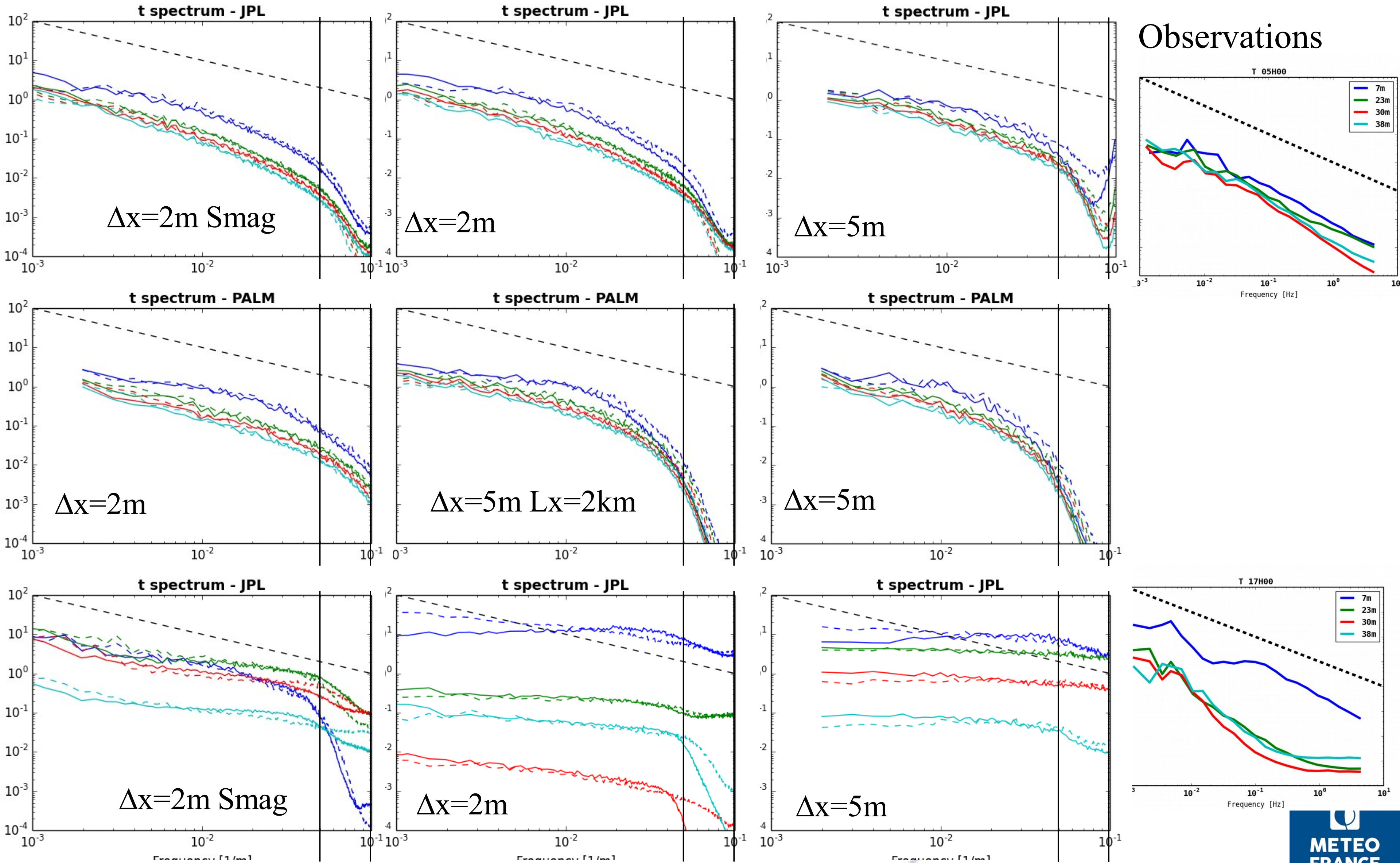
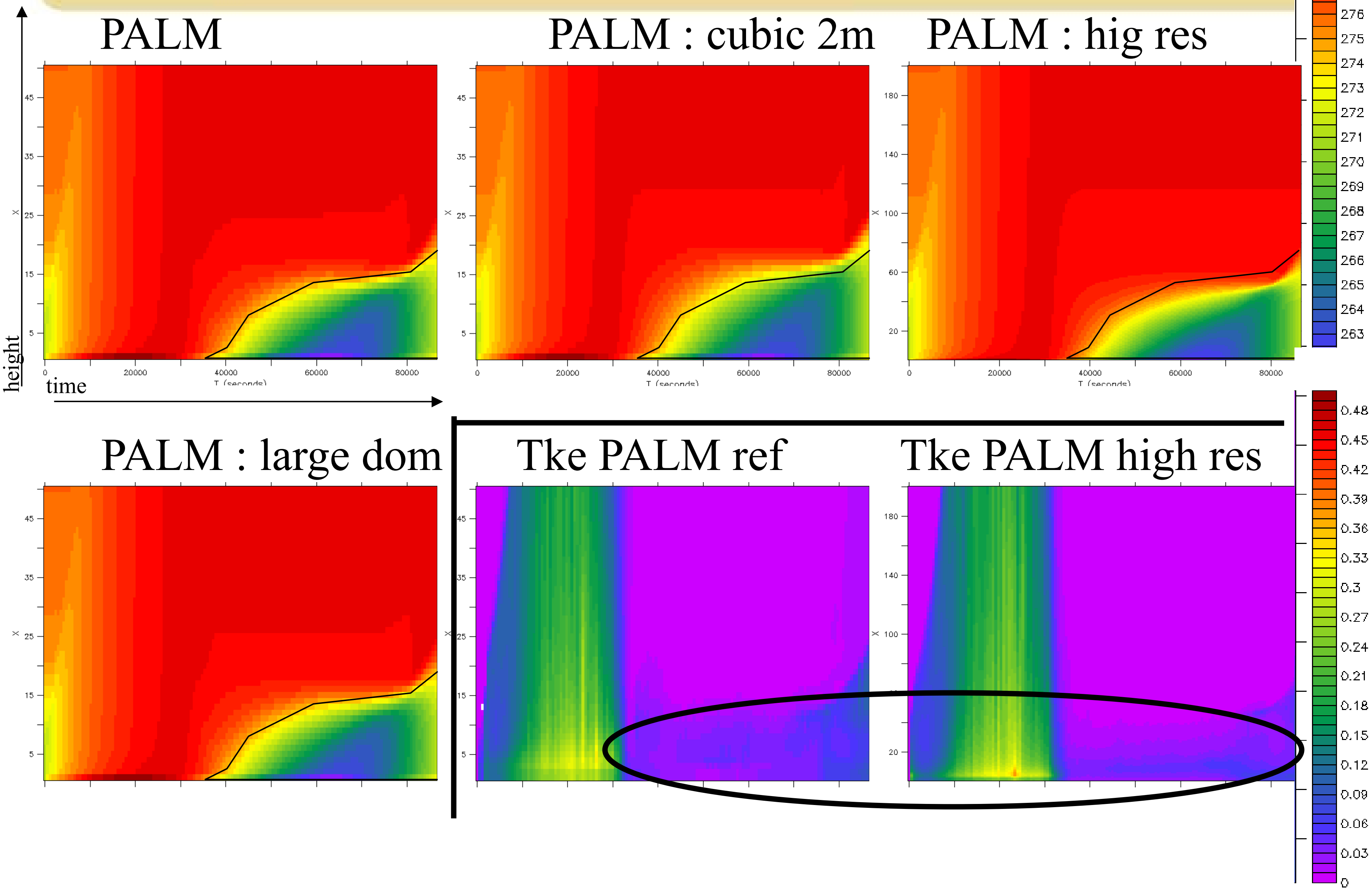




LES intercomparison : spectrum at observed levels

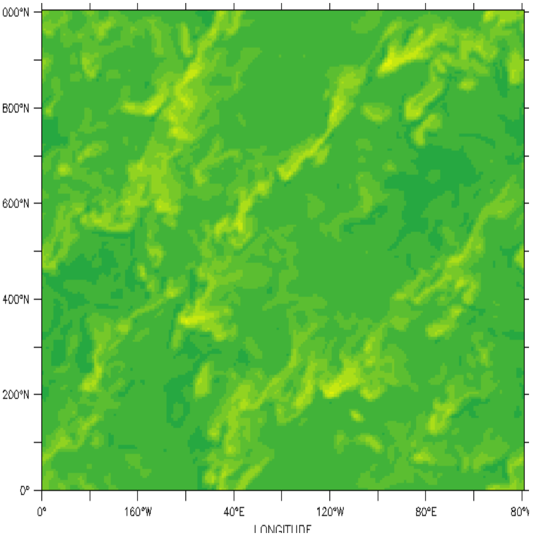


Sensitivity to the resolution : temperature evolution

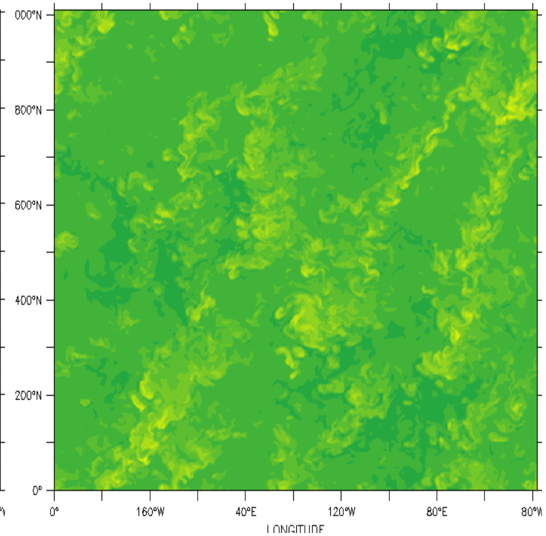


Sensitivity to the resolution : cross sections
T at 31m 05TU (upper panels) / u at 9m 17TU (lower panels)

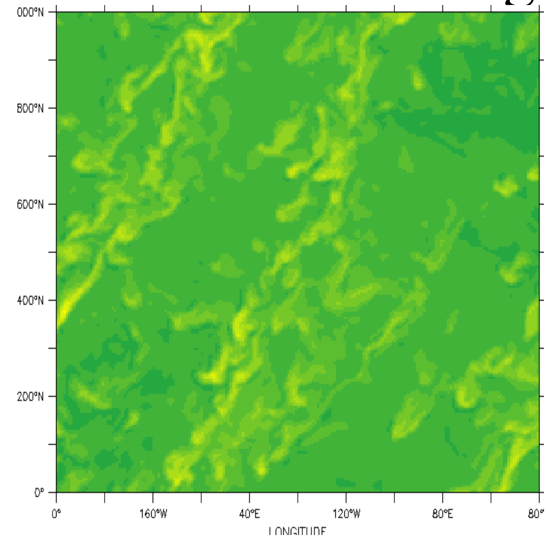
PALM

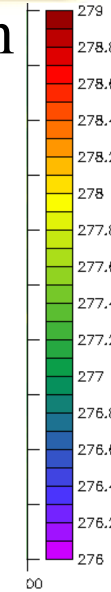


PALM : cubic

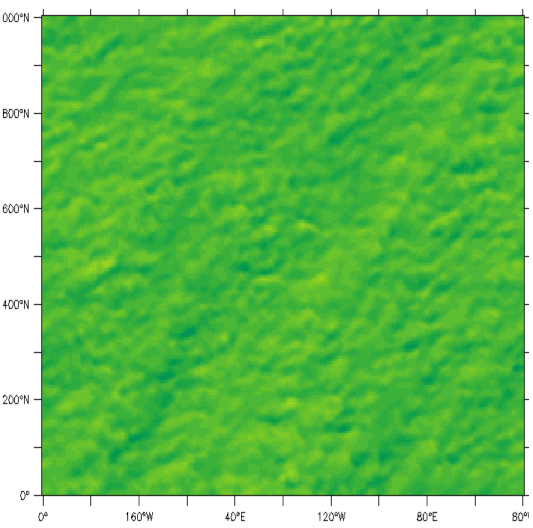


PALM : larger dom

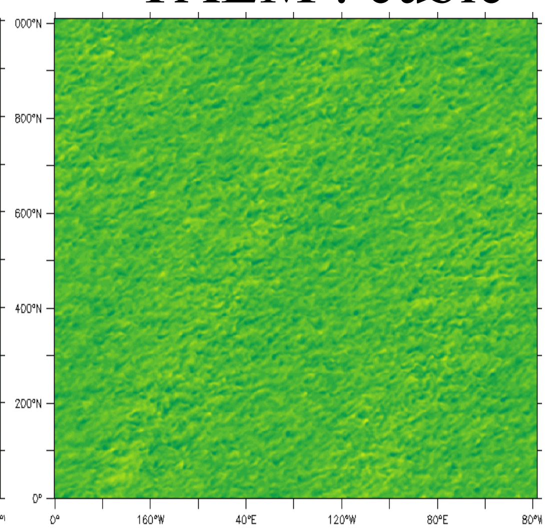




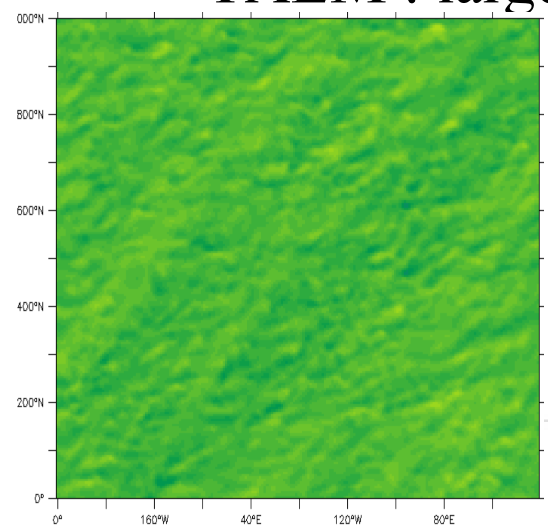
PALM

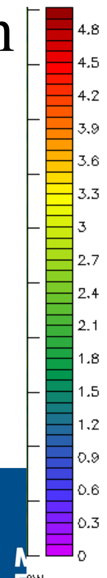


PALM : cubic



PALM : larger dom





Presentation of the various LES for stage 3

LES model	Horizontal resolution	Vertical resolution	Top of the domain	Domain size	Time step	Advection scheme (finite differences except noted)	Temporal scheme
MesoNH	5m/25m	2m (streched z>400m) stretched (1m-> 10m z<400m)	Sponge layer for z> 700m K=0.001	1x1x1 km^3 5x5x1.6km^3	0.2s/0.3s	Scalars : monotonic Piecewise Parabolic Method Momentum : 4th order centered	Leap-frog scheme + asselin filter
PALM	5m/2m/1m	2m/2m/0.5m	Sponge layer z> 700m	1x1x1km^3 2.5x2.5x1km^3	Variable (CFL<1 0.65-0.9s ; 0.13-0.17s	Scalars & momentum : 5th order advection scheme (Wicher, Skamarock 2002)	Third-order Runge Kutta
JPL	5m	2m	Sponge layer for z> 700m τ=600s	1x1x1km^3	Variable (CFL< 1.4 ;0.8-1.5s)	Scalars and momentum : sixth-order fully conservative scheme	Third-order Runge Kutta
MicroHH	5m	2m	Sponge layer z> 700m	3x3x0.5km^3	Variable (CFL < 1.2)	Scalars and momentum : 2nd order with 4th order interpolations	Third-order Runge Kutta
CLMM	5m	2m	Sponge layer z> 600m	1x1x1km^3	Variable (CFL < 0.7)	Scalars : k=1/3 scheme momentum : 2nd order symetric centered differences	Third-order Runge Kutta with a fractional step method
NCSU	10m	10m	z> 600m K increases with height	1x1x1km^3	0.25s	*pseudo-spectral code (spectral in horizontal direction; 2nd-order finite difference in vertical)*	Second-order Adams-Bashforth
SAM-IPHOC	100m	5m-> 300m (z<400m) → 10km (z=29km)	z>19km	6.4x6.4x1km^3	2s	Scalars and momentum : 5th order ULTIMATE-MACHO for non-uniform vertical grid	Third-order Adams-Bashforth
SAM-IPHOC-HR	5m	2m	???	1x1x1km^3	0.5	Scalars and momentum : 5th order ULTIMATE-MACHO for non-uniform vertical grid	Third-order Adams-Bashforth

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Presentation of the various LES for stage 3

LES model	Subgrid turbulence scheme	Surface scheme
MesoNH	Tke-l type with l equals to Deardorff length-scale : gradient approach with sgs eddy-diffusivities and a prognostic equation for sgs-tke	ISBA (Noilhan et al 1989) surface scheme
PALM	1.5 order scheme after Deardorff (1980) : gradient approch sith sgs eddy diffusivities and a prognostic equation for sgs-tke	Monin-Obukhov similarity theory
JPL	Buoyancy adjusted stretched vortex model : a bit different than tke-Smagorinskiy tupe with functional closures (Cung and Matheou 2014)	Monin-Obukhov similarity theory
MicroHH	Smagorinsky-Lilly stability correction from Lilly (1962) Fixed Prandtl number (1/3) wall-damping near the surface	Monin-Obukhov similarity theory with stability functions following Wilson (2001) for unstable condition and Hogstrom (1988) for stable conditions
CLMM	Sigma sgs model with an experimental stability correction	Monin-Obukhov similarity theory applied locally, fluxes computed iteratively
NCSU	Locally-averaged scale-dependent dynamic model (LASDD) Both Smagorinski coefficient and Prandtl numbers are determined dynamically	Monin-Obukhov similarity theory
SAM-IPHOC	IPHOC (intermediately prognostic higher-order turbulence closure) : prognostic equations for 2nd & 3rd moments + Joint double gaussian distribution for thl, rt,w => 4th order moments & cloud variables	Monin-Obukhov similarity theory

METEO FRANCE

Resolution of fluxes for the various LES

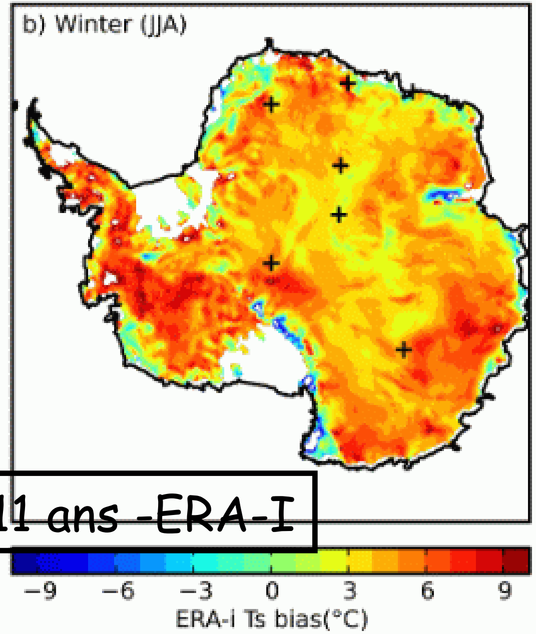
Les models	En stable	En instable
Meso-NH		
PALM	$\Phi_m = -3\zeta^{\frac{5}{6}}$, $\Phi_h = -2.5\zeta^{\frac{4}{5}}$.	$\Phi_m = \log\left(\frac{1+x^2}{2}\left(\frac{1+x}{2}\right)^2\right) - 2\arctan(x) + \pi/2$, $\Phi_h = 2\log\left(\frac{1+x^2}{2}\right)$,
JPL		
MicroHH		

$$x = (1-6\zeta)^{1/4}$$

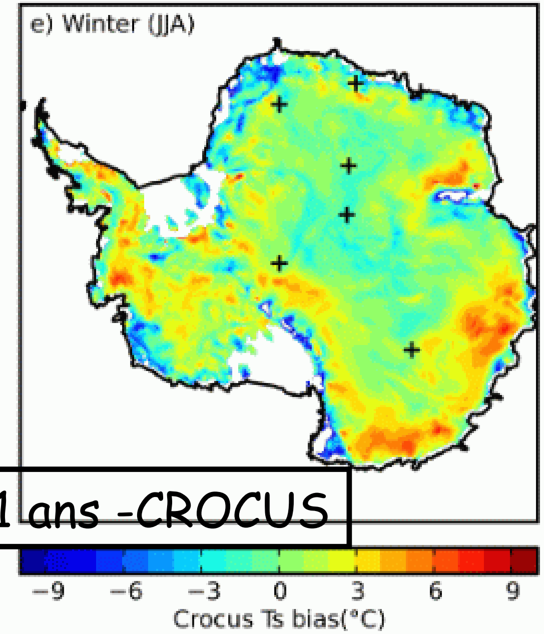
M-O similarity u*, θ*=f(du/dz,dθ/dz, Φm Φh, z/Lmo)

$$ustar = Kz \times \frac{\partial u}{\partial z} \times Phim(z/Lmo)$$

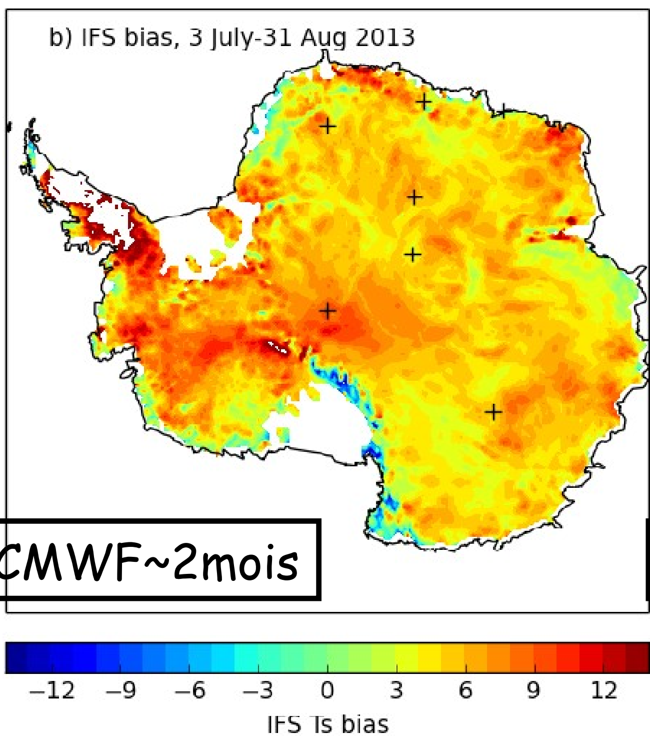
Biais de température de surface /MODIS (Freville et al. 2014)



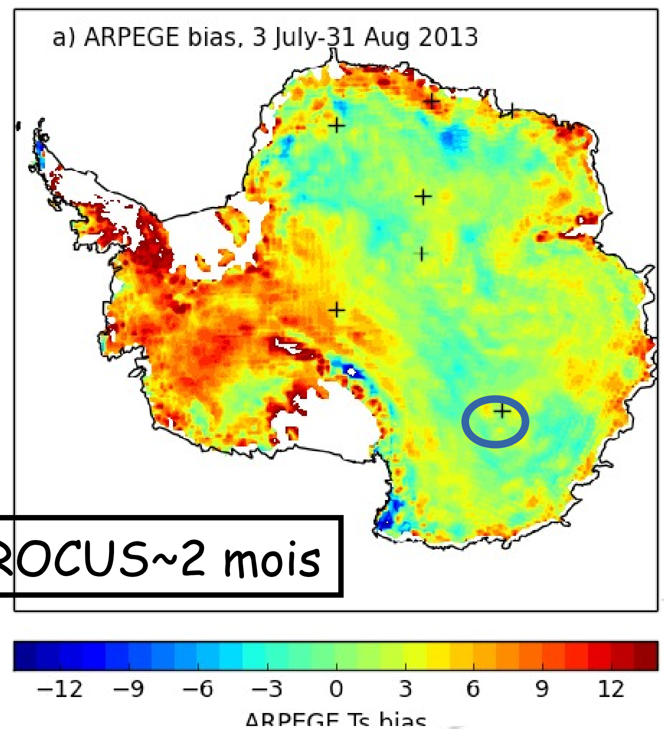
11 ans -ERA-I



11 ans -CROCUS



ECMWF~2mois



CROCUS~2 mois